PB86-107943

Survey of Trichloroethylene Emission Sources

Radian Corp., Research Triangle Park, NC

Prepared for

Environmental Protection Agency
Research Triangle Park, NC

Jul 85

U.S. Department of Commerce
National Technical Information Service
NTIS

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-450/3-85-021	2.	3. RECIPIENT'S ACCESSION NO. PB86 107943/AS
4. TITLE AND SUBTITLE Survey of Trichloroethylene Emission Sources		5. REPORT DATE July 1985 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) R.F. Pandullo, S.A. Shareef, L.E. Kincaid, P.V. Murphy Radian Corporation - Post Office Box 13000 Research Triangle Park, North Carolina 27709		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Office of Air Quality Planning and Standards Environmental Protection Agency Research Triangle Park, North Carolina 27711		10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO. EPA Contract 68-02-3816
12. SPONSORING AGENCY NAME AND ADDRESS DAA for Air Quality Planning and Standards Office of Air and Radiation U.S. Environmental Protection Agency Research Triangle Park, North Carolina 27711		13. TYPE OF REPORT AND PERIOD COVERED Final 14. SPONSORING AGENCY CODE EPA/200/04

15. SUPPLEMENTARY NOTES

16. ABSTRACT

The potential health impact of trichloroethylene emissions is being investigated. This document contains information on the sources of trichloroethylene emissions, current emission levels, control methods that could be used to reduce trichloroethylene emissions, and cost estimates for employing controls.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air Pollution Pollution Control Synthetic Organic Chemical Manufacturing Industry Trichloroethylene	Air Pollution Control	13B

18. DISTRIBUTION STATEMENT Unlimited	19. SECURITY CLASS (This Report) Unclassified	21. NO. OF PAGES 133
	20. SECURITY CLASS (This page) Unclassified	22. PRICE A16.95

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

United States
Environmental Protection
Agency

Office of Air Quality
Planning and Standards
Research Triangle Park NC 27711

EPA-450/3-85-021
July 1985

Air

EPA

PB86-107943

Survey of Trichloroethylene Emission Sources

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

NESHAP

EPA-450/3-85-021

Survey of Trichloroethylene Emission Sources

Emission Standards and Engineering Division

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Radiation
Office of Air Quality Planning and Standards
Research Triangle Park, NC 27711

July 1985

i, a

This report has been reviewed by the Emission Standards and Engineering Division of the Office of Air Quality Planning and Standards, EPA, and approved for publication. Mention of trade names or commercial products is not intended to constitute endorsement or recommendation for use. Copies of this report are available through the Library Services Office (MD-35), U.S. Environmental Protection Agency, Research Triangle Park, N. C. 27711, or from National Technical Information Services, 5285 Port Royal Road, Springfield, Virginia 22161.

TABLE OF CONTENTS

Chapter — Page

1.0 INTRODUCTION AND SUMMARY 1-1

- 1.1 INTRODUCTION. 1-1
- 1.2 SUMMARY 1-2
  - 1.2.1 TCE Emission Source Categories 1-2
  - 1.2.2 Emission Estimates 1-2
  - 1.2.3 Additional Control of TCE Emissions. 1-5
  - 1.2.4 Regulatory Requirements. 1-6
- 1.3 REFERENCES. 1-10

2.0 TRICHLOROETHYLENE PRODUCTION 2-1

- 2.1 QUANTITIES PRODUCED AND MANUFACTURERS 2-1
- 2.2 PROCESS DESCRIPTIONS, EMISSIONS, AND CURRENT CONTROLS. 2-1
  - 2.2.1 Chlorination of Ethylene Dichloride (EDC). . . 2-3
    - 2.2.1.1 Process Description 2-3
    - 2.2.1.2 Current Emissions and Controls. . . . 2-3
  - 2.2.2 Oxychlorination of Ethylene Dichloride (EDC). 2-8
    - 2.2.2.1 Process Description 2-8
    - 2.2.2.2 Current Emissions and Controls. . . . 2-8
- 2.3 COST OF ADDITIONAL CONTROLS 2-13
  - 2.3.1 Control of Process Vent Emissions. 2-13
  - 2.3.2 Control of Equipment Leak Emissions. 2-13
  - 2.3.3 Control of Storage Emissions 2-16
  - 2.3.4 Control of Loading Emissions 2-16
- 2.4 REFERENCES. 2-17

3.0 OTHER CHEMICAL PRODUCTION. 3-1

- 3.1 PROCESS DESCRIPTIONS, EMISSIONS, AND CURRENT CONTROLS. 3-1
  - 3.1.1 Ethylene Dichloride (EDC)/Vinyl Chloride Monomer (VCM) Manufacture. 3-1
    - 3.1.1.1 Process Description 3-2
    - 3.1.1.2 Current Emissions and Controls. . . . 3-2
  - 3.1.2 Polyvinyl Chloride (PVC) Manufacture 3-8
    - 3.1.2.1 Process Description 3-8
    - 3.1.2.2 Current Emissions and Controls. . . . 3-8

TABLE OF CONTENTS (Continued)

Chapter Page

3.1.3 Vinylidene Chloride Manufacture. 3-9
3.1.3.1 Process Description 3-9
3.1.3.2 Current Emissions and Controls. . . 3-10
3.1.4 Storage of TCE for Resale. 3-10
3.1.4.1 Current Emissions and Controls. . . 3-11

3.2 COST OF ADDITIONAL CONTROLS 3-12
3.2.1 Control of Equipment Leaks 3-12
3.2.2 Control of Storage Emissions 3-15

3.3 REFERENCES. 3-16

4.0 SOLVENT DEGREASING OPERATIONS. 4-1

4.1 INDUSTRY DESCRIPTION. 4-1

4.2 DEGREASING EQUIPMENT. 4-2

4.3 EMISSIONS FROM DEGREASING OPERATIONS. 4-3

4.4 EMISSIONS CONTROL 4-5

4.5 COST OF EMISSIONS CONTROL 4-8

4.6 REGULATORY REQUIREMENTS 4-14

4.7 REFERENCES. 4-15

5.0 DISTRIBUTION FACILITIES. 5-1

5.1 EMISSIONS FROM DISTRIBUTION FACILITIES. 5-1

5.2 REGULATORY REQUIREMENTS 5-3

5.3 REFERENCES. 5-4

6.0 MISCELLANEOUS SOURCES. 6-1

6.1 REFERENCES. 6-3

7.0 PUBLICLY OWNED TREATMENT WORKS (POTWS) 7-1

7.1 EMISSION ESTIMATES. 7-1

7.2 REFERENCES. 7-2

TABLE OF CONTENTS (Continued)

Chapter Page

APPENDIX A: MATERIAL BALANCE FOR TCE EMISSIONS FROM DEGREASING OPERATIONS A-1

A.1 MATERIAL BALANCE. A-1

A.2 NATIONAL EMISSION REDUCTION CALCULATIONS. . . . A-2

A.3 REFERENCES. A-6

APPENDIX B: METHODS USED FOR ESTIMATING STORAGE TANK AND EQUIPMENT LEAK EMISSIONS B-1

B.1 EMISSION FACTORS FOR FIXED-ROOF STORAGE TANKS B-1
  B.1.1 Emission Equations B-1
  B.1.2 Parameter Values and Assumptions B-1
  B.1.3 Sample Calculation B-2

B.2 EMISSION FACTORS FOR INTERNAL FLOATING ROOF STORAGE TANKS B-4
  B.2.1 Emission Equations B-4
  B.2.2 Parameter Values and Assumptions B-4
  B.2.3 Sample Calculation B-6

B.3 EQUIPMENT LEAK EMISSIONS - SAMPLE CALCULATIONS. B-10

B.4 REFERENCES. B-12

APPENDIX C: METHODS FOR ESTIMATING EMISSION CONTROL COSTS. . . . C-1

C.1 PROCESS VENT EMISSIONS CONTROL COST ESTIMATION. C-1

C.2 COST CALCULATIONS FOR INSTALLING INTERNAL FLOATING ROOFS IN FIXED ROOF TANKS. C-7
  C.2.1 Capital Cost C-7
  C.2.2 Annual Cost. C-15
  C.2.3 C_2HCl_3/VOC Reduction C-15
  C.2.4 Recovery Credits C-16
  C.2.5 Net Annual Cost. C-16
  C.2.6 Cost Effectiveness C-16

TABLE OF CONTENTS (Continued)

Chapter Page

C.3 COST CALCULATIONS FOR INSTALLATION OF REFRIGERATED CONDENSERS TO CONTROL LOADING EMISSIONS . . . C-17

C.4 SAMPLE CALCULATIONS FOR EQUIPMENT LEAK CONTROL COSTS C-20

C.5 REFERENCES. C-23

APPENDIX D: SUMMARY OF EXISTING STATE AND FEDERAL REGULATIONS AFFECTING TRICHLOROETHYLENE EMISSION SOURCES . . . D-1

D.1 EXISTING STATE REGULATIONS. D-1
D.1.1 Introduction D-1
D.1.2 General State VOC Regulations for Solvent Use. D-1
D.1.3 Prevention of Significant Deterioration Regulations. D-1
D.1.4 State Regulations Affecting Chemical Production D-3

D.2 EXISTING FEDERAL REGULATIONS. D-3

APPENDIX E: TRICHLOROETHYLENE EMISSIONS FROM DISTRIBUTION FACILITIES E-1

E.1 TRICHLOROETHYLENE EMISSIONS FROM DISTRIBUTION FACILITIES. E-1

LIST OF TABLES

Table		Page
1-1	EMISSIONS IN 1983 FROM THE PRODUCTION AND USE OF TRICHLOROETHYLENE	1-3
1-2	ACHIEVABLE TCE EMISSION REDUCTIONS FROM CHEMICAL PRODUCTION FACILITIES AND DEGREASERS AS A FUNCTION OF COST EFFECTIVENESS.	1-7
2-1	TRICHLOROETHYLENE PRODUCTION PLANTS	2-2
2-2	TOTAL EMISSIONS FROM TRICHLOROETHYLENE PRODUCTION FACILITIES.	2-5
2-3	ESTIMATED EMISSIONS AND CURRENT CONTROLS AT THE FACILITY PRODUCING TRICHLOROETHYLENE BY THE CHLORINATION OF EDC	2-6
2-4	ESTIMATED EMISSIONS AND CURRENT CONTROLS AT THE FACILITY PRODUCING TRICHLOROETHYLENE BY THE OXYCHLORINATION OF EDC	2-10
2-5	COST OF ADDITIONAL CONTROLS AT TCE PRODUCTION FACILITIES (1984 DOLLARS)	2-14
2-6	ESTIMATED TCE EMISSION REDUCTIONS AT TCE PRODUCTION FACILITIES.	2-15
3-1	TOTAL EMISSIONS FROM OTHER CHEMICAL PRODUCTION FACILITIES.	3-3
3-2	ESTIMATED EMISSIONS AND CURRENT CONTROLS AT FACILITIES USING TRICHLOROETHYLENE	3-4
3-3	ESTIMATED COST OF ADDITIONAL CONTROL DEVICES AT OTHER CHEMICAL PRODUCTION FACILITIES	3-13
3-4	ESTIMATED TCE EMISSION REDUCTIONS FOR OTHER CHEMICAL PRODUCTION FACILITIES AS A FUNCTION OF COST EFFECTIVENESS	3-14
4-1	1983 TCE EMISSIONS FROM DEGREASING OPERATIONS, BY INDUSTRY.	4-4
4-2	1983 TRICHLOROETHYLENE EMISSIONS FROM DEGREASING OPERATIONS, BY STATE.	4-6

LIST OF TABLES (Continued)

Table Page

4-3 EXAMPLE CONTROL TECHNIQUES FOR DEGREASERS 4-7

4-4 RETROFIT CONTROL COSTS FOR COLD CLEANERS. 4-9

4-5 RETROFIT CONTROL COSTS FOR MEDIUM SIZE OPEN TOP VAPOR DEGREASER 4-10

4-6 RETROFIT CONTROL COSTS FOR CONVEYORIZED DEGREASERS. . . 4-12

5-1 SUMMARY OF MAJOR TRICHLOROETHYLENE DISTRIBUTORS 5-2

6-1 1983 TRICHLOROETHYLENE CONSUMPTION AND EMISSIONS FROM OTHER CHEMICAL PRODUCTION SOURCE CATEGORIES 6-2

B-1 PAINT FACTORS FOR FIXED ROOF TANKS. B-3

B-2 TYPICAL NUMBER OF COLUMNS AS A FUNCTION OF TANK DIAMETERS B-7

B-3 SUMMARY OF DECK FITTING LOSS FACTORS (K_f) AND TYPICAL NUMBER OF FITTINGS (N_f) B-8

C-1 TOTAL INSTALLED CAPITAL COST AS A FUNCTION OF VENT STREAM FLOW RATE C-2

C-2 ADDITIONAL DUCT COST. C-3

C-3 PIPE RACK COST. C-4

C-4 OPERATING FACTORS FOR EACH DESIGN CATEGORY. C-5

C-5 ANNUALIZED COST FACTORS C-6

C-6 SAMPLE CALCULATION FOR INCINERATOR COSTING. C-7

C-7 COST CONVERSION FACTORS C-13

C-8 CONTROL TECHNIQUES AND COST FOR CONTROLLING EQUIPMENT LEAK EMISSION SOURCES C-20

D-1 GENERAL STATE VOC REGULATIONS FOR PHOTOCHEMICAL SOLVENTS. D-2

LIST OF TABLES (Continued)

Table Page

D-2 STATE REGULATIONS AFFECTING CHEMICAL PRODUCTION FACILITIES. D-4

D-3 SUMMARY OF FEDERAL REGULATIONS AFFECTING TRICHLOROETHYLENE EMITTING SOURCES. D-7

LIST OF FIGURES

Figure		Page
2-1	Process Flow Diagram for the Production of Trichloroethylene by Direct Chlorination	2-4
2-2	Process Flow Diagram for the Production of Trichloroethylene by Oxychlorination	2-9
C-1	Cascade Refrigeration System for Vapor Recovery.	C-18

1.0 INTRODUCTION AND SUMMARY

1.1 INTRODUCTION

This document identifies the sources and locations of trichloroethylene (TCE) emissions, estimates total production and consumption volumes, estimates emission levels, identifies applicable control techniques for each source, and estimates the cost effectiveness of controlling emissions for several source types. The information collected in this source assessment study will also be used by the U.S. Environmental Protection Agency (EPA) to estimate human exposure to TCE.

Information for this document was acquired from various sources. Background information, such as previous EPA documents and other published literature, was reviewed in an attempt to identify the producers of TCE and the major applications. Two companies producing TCE at two facilities were identified. Four companies using TCE or emitting TCE as a byproduct were also identified. Further, ethylene dichloride (EDC) production was identified as a source of byproduct TCE formation. A total of twelve companies producing EDC were identified, one of which also produces TCE.

Under authority of Section 114 of the Clean Air Act, letters were sent to the two companies producing TCE, the four companies using or emitting TCE as a byproduct in various chemical production processes, and to nine of the twelve EDC producers. Information was requested concerning TCE emissions, emission levels, and control techniques for all possible emission sources associated with the production, storage, and use of TCE in the calendar year 1983. General information such as production volumes and total sales/purchase data were also requested in order to verify the completeness of the submitted information. The production and sales/purchase information was requested to be treated as confidential and is not discussed in this report. For each process unit making or consuming TCE, detailed information was requested on the following emission types: process vent emissions, equipment leaks, equipment opening losses, raw material/product storage emissions, loading/

handling emissions, and secondary emissions. The companies were asked only to estimate these emissions. No testing was required specifically for this information request.

Information was obtained from the Halogenated Solvents Industry Alliance (HSIA), a trade group representing the producers of TCE and other halogenated solvents, regarding the total amounts of TCE used in 1983 for various applications.[1] Using this and other available information, emission levels in 1983 were estimated for each application. The major use of TCE was identified to be solvent degreasing.

1.2 SUMMARY

1.2.1 TCE Emission Source Categories

Trichloroethylene is produced by two chemical companies at two plants in the United States. The estimated total 1983 production volume of TCE was 65,700 Mg.[1] Two processes are used to produce TCE: (1) chlorination of ethylene dichloride, and (2) oxychlorination of ethylene dichloride.[2] In 1983, 85 percent of the TCE produced was used as a solvent in degreasing operations, and 15 percent was used in a variety of other applications. These other applications include use as a solvent in adhesives manufacture, paints and coatings manufacture, and as a reaction chain transfer agent in the production of polyvinyl chloride (PVC).

Emission estimates have been made in this study for the following categories: TCE production, other chemical production (TCE as a by-product, and use as a reaction chain transfer agent), degreasing operations, distribution facilities, publicly-owned treatment works (POTW), and miscellaneous applications.

1.2.2 Emission Estimates

The total emissions from TCE production and use in 1983 were 57,600 Mg/yr. The largest sources of emissions were degreasing operations (52,600 Mg/yr) and POTW operations (1,450 Mg/yr). All identified emission sources and corresponding esimated emissions are shown in Table 1-1.

TABLE 1-1. EMISSIONS IN 1983 FROM THE PRODUCTION AND USE OF TRICHLOROETHYLENE

Emission Source	Production/ Consumption (Mg/Yr)	Emissions (Mg/Yr)
TCE Production	65,700	100
Other Chemical Production	N/A	28[a]
Degreasing Operations	56,000	52,600
Distribution Facilities	65,700[b]	39
POTW Operations	-	1,400
Adhesive Formulations	420	420
Paints and Coatings	520	520
PVC Production	6,500[c]	130[c]
Miscellaneous	2,340	2,340
TOTAL	197,200	57,600

N/A - Not available.

[a] Includes estimated 21 Mg TCE emissions as a by-product from other EDC/VCM facilities (see Section 3.1.1).

[b] Estimated amount sold through distributors.

[c] Based on a 1978 EPA/OPTS study.

Trichloroethylene emissions from TCE production processes are estimated to be 100 Mg/yr. TCE emissions from other chemical production facilities are estimated to be 28 Mg/yr. About 7 Mg/yr of the 28 Mg/yr were emitted from two EDC plants where TCE was reported to be formed as a by-product, two chlorinated solvent plants where TCE is not produced but is stored to maintain a full line of solvents, one polyvinyl chloride (PVC) plant where TCE is used as a reaction chain transfer agent, and one vinylidene chloride plant where TCE is formed as a by-product. About 21 Mg/yr of the 28 Mg/yr were estimated to be emitted from other EDC plants where TCE is suspected to be emitted as a by-product. No data were obtained directly from these other EDC plants. Emissions were estimated to be proportional to the emissions from the two EDC facilities reporting TCE emissions.

The chemical plant emission estimates were obtained from company responses to Section 114 requests. Included in these chemical plant emission estimates are emission estimates from process vents (estimated at full capacity), loading/handling operations, equipment opening losses, pressure relief valve discharges, equipment leaks, storage tanks, and secondary streams. Volatile organic compound (VOC) emissions from equipment leaks were calculated by applying the Synthetic Organic Chemical Manufacturing Industry (SOCMI) VOC equipment leak emission factors to the equipment count provided by each company.[3] TCE emissions were estimated by applying the volume percent of TCE passing through each piece of equipment in TCE service to the calculated VOC emissions. Emissions from storage tanks were estimated by using AP-42 equations and storage tank data supplied by each company.[4] Detailed methods for estimating these emissions are described in Appendix B.

Trichloroethylene emissions from degreasing operations were estimated to be 52,600 Mg in 1983. Degreasing operations represented the largest source category of TCE emissions in 1983, accounting for about 91 percent of total TCE emissions. Degreasing emission estimates were made using HSIA information on 1983 TCE consumption in various applications and available emission factors. The HSIA indicated that TCE was used as a degreasing solvent in five major industry groups in 1983. These are: furniture and fixtures (Standard Industrial Classification (SIC) 25), fabricated metal products (SIC 34), electric and electronic equipment (SIC 36), transportation equipment (SIC 37), and miscellaneous industries (SIC 39). Emission factors for degreasing operations were obtained from previous EPA studies. The methodology for calculating the overall emission factor for degreasing is presented in Appendix A.

Almost all of the TCE produced is sold through various chemical distributors. The handling and storage operations at distribution facilities located throughout the country were estimated to account for 39 Mg of TCE emissions in 1983.

Recent EPA studies have estimated that about 1,450 Mg of TCE emissions occur annually at POTW operations. These emissions are believed to occur through volatilization from industrial discharges of waste streams containing TCE.

Additional applications of TCE include primarily use in adhesives manufacture, paints and coatings manufacture, and as a reaction chain transfer agent in the production of PVC. These applications were estimated to account for about 3,400 Mg of TCE emissions in 1983. Adhesives, paints, and coatings have largely consumer applications. Thus, it is estimated that all TCE used in these applications is emitted to the atmosphere. For use of TCE in PVC production, it is estimated that about two percent of consumption is emitted to the atmosphere. The identities of all PVC manufacturers emitting TCE is presently not known.

1.2.3 Additional Control of TCE Emissions

The cost associated with additional control of TCE emissions was estimated for TCE production facilities, other chemical production facilities, and degreasers. Due to the large number of degreasers, no attempt was made to develop cost estimates for each degreaser actually in use. Instead, cost estimates were developed for model degreasers. National costs and national emission reductions associated with controlling degreasers were based on the model degreaser data. Specific information was provided for TCE production and other chemical production facilities. This information was used to develop national cost and emission reduction estimates to be for these production facilities.

Emissions of TCE from chemical plants producing or using TCE can be reduced by various technically feasible controls. Process vent emissions can be controlled by incineration. Equipment leak emissions can be reduced through a combination of leak detection and repair programs and application of equipment control devices. Storage tank emissions can be reduced by installation of floating roofs in fixed roof tanks. Where floating roofs are not technically feasible (i.e. horizontal tanks or extremely small diameter tanks), a refrigerated condenser can be used for control of storage emissions. Loading emissions can be controlled by venting displaced vapors to a refrigerated condenser. The methodology for estimating cost effectiveness of control is presented in Appendix C.

Emissions of TCE from degreasers can be reduced by using covers for degreaser openings, increasing degreaser freeboard area, adding freeboard chillers, providing drainage racks for parts, and installing carbon adsorbers. The methodology for estimating cost effectiveness of control is presented in Chapter 4.

Costs were estimated for the above control techniques for all emission sources which are not presently well controlled. These costs estimates are based on the information provided in the company Section 114 responses on the emission stream and process equipment parameters and also on the data for model degreasers. It is estimated that about 26,200 Mg/yr TCE emissions can be controlled by the application of control techniques on process vent, equipment leak storage tanks, and handling emissions at TCE production and other chemical plants and by application of control techniques on uncontrolled degreasers. This represents an overall emission reduction of about 50 percent over current estimated emissions. Table 1-2 shows the emission reduction for each emission type for various ranges of cost effectiveness.

1.2.4 Regulatory Requirements

The 8 plants that produce TCE, manufacture TCE as a byproduct, or store TCE are located in four States: Texas, Louisiana, Kansas, and Illinois. The VOC emissions from these existing chemical production facilities are not

TABLE 1-2. ACHIEVABLE TCE EMISSION REDUCTIONS FROM CHEMICAL PRODUCTION FACILITIES AND DEGREASERS AS A FUNCTION OF COST EFFECTIVENESS

	Emission Reduction, Mg/Yr					
Cost Effectiveness Range ($/Mg VOC)	Process Vents	Equipment Leak	Storage Tanks	Loading	Degreasing	Total
Credit	-	-	-	-	-	-
0 - 500	-	-	-	-	11,270	11,270
500 - 1,000	-	32.5	1.0	-	-	33.5
1,000 - 2,000	-	-	0.1	-	14,900	14,900
2,000 - 5,000	-	0.4	0.4	-	-	0.8
>5,000	0.3	-	16.6	13.8	-	30.7
TOTAL	0.3	32.9	18.1	13.8	26,170	26,230

controlled by Federal regulations such as the new source performance standards (NSPS) for volatile organic compounds in the synthetic organic chemical manufacturing industry. However, the EDC/VCM plants producing TCE as a byproduct and the PVC plant using TCE as a reaction chain transfer agent may be controlled by the national emission standards for hazardous air pollutants (NESHAP) for vinyl chloride (VC). Also, the emissions at most plants are controlled to some extent in each of these States by county, district, or State regulations.

Trichloroethylene emissions from process vents are restricted by State or district VOC regulations in Texas, Louisiana, and Illinois. Texas regulations require emissions to be properly incinerated at 1300°F. Process vent streams emitting less than 45 kg/day and 110 kg/hr in any 24 hour period are exempt from this regulation. Louisiana requires incineration at 1300°F with a 0.3 second residence time. However, the control requirements can be waived of the VOC emissions are less than 91 Mg/yr or will not support combustion, or if control will cause economic hardship. Illinois regulations limit VOC emissions to 100 ppm equivalent methane.

Equipment leak emissions are not presently regulated in any of the four States. However, both Texas and Louisiana have recently enacted regulations for equipment leaks with a final compliance date of December 31, 1987. In Texas the requirements will include annual testing of all valves in liquid service, capping of open-ended lines and valves, monitoring of pump seals, and detailed recordkeeping of these practices. In Louisiana the requirements will include annual monitoring of pump seals, pipeline valves in liquid service, and process drains, and quarterly monitoring of compressor seals, pipeline valves in gas service, and relief devices.

Texas, Louisiana, and Illinois have regulations for VOC emissions from storage tanks. In general, tanks greater than 40,000 gallons storing liquids with a vapor pressure greater than 1.5 psia and less than 11.0 psia are required to be controlled by an internal floating roof with a primary seal, an internal floating roof with both primary and secondary seals, refrigerated condensers, or incineration. Kansas regulates only emissions from storage tanks containing petroleum.

VOC emissions from loading/handling operations are regulated by Texas, Louisiana, and Illinois. Texas and Louisiana require vapor collection and recovery or disposal for facilities loading greater than 20,000 gal/day (40,000 gal/day for existing facilities in Louisiana). Illinois requires submerged fill.

There are no Federal regulations for TCE emissions from degreasing operations. A CTG for organic solvent cleaners has been issued by EPA establishing RACT guidelines that have been used by State agencies to develop SIPs. Thirty two states and the District of Columbia have adopted RACT for use of TCE in degreasing operations. Eighteen states have not adopted any regulations. Further details on state regulations are contained in Appendix D.

1.3 REFERENCES

1. Letter from D. L. Morgan, Cleary, Gottlieb, Steen, and Hamilton, to R. E. Rosensteel, EPA/ESED. February 22, 1985. Response for Halogenated Solvents Industrial Alliance concerning industrial consumption volumes of trichloroethylene in 1983.

2. Mannsville Chemical Products. Chemical Products Synopsis - Trichloroethylene. Cortland, New York. November 1984.

3. U.S. Environmental Protection Agency. Fugitive Emission Sources of Organic Compounds - Additional Information on Emissions, Emission Reductions and Costs. Research Triangle Park, North Carolina. Publication No. EPA-450/3-82-010.

4. Compilation of Air Pollutant Emission Factors, 3rd Edition. U. S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Monitoring and Data Analysis Division. Research Triangle Park, N.C. January 1984.

2.0 TRICHLOROETHYLENE PRODUCTION

This chapter presents the emissions and controls associated with the production of trichloroethylene (TCE) at the two production facilities in the United States. Emissions from TCE production facilities come from process vents, storage tanks, equipment openings, equipment leaks, handling operations, relief device discharges, and secondary (disposal) sources.

TCE is currently produced by two processes. These are the direct chlorination of ethylene dichloride (EDC) and a single-step oxychlorination of EDC.

2.1 QUANTITIES PRODUCED AND MANUFACTURERS

TCE is currently produced by two companies at two facilities. The estimated total production capacity of these plants in 1983 was approximately 154,600 Mg/yr.[1] In 1983 about 65,700 Mg of TCE were produced.[2] The total imports of TCE in 1983 were 14,900 Mg, and total exports were 14,500 Mg indicating a total domestic demand of about 66,000 Mg. The producers, their capacities, and production processes are listed in Table 2-1.

Vulcan Chemicals is proceeding with engineering studies for a new TCE facility despite a poor market outlook.[1] Demand for TCE is expected to decrease in 1985, possibly due to the presence of improved solvent recovery systems and the impact of regulatory constraints.

2.2 PROCESS DESCRIPTIONS, EMISSIONS, AND CURRENT CONTROLS

This section presents the emission estimates and current controls for the two producers of TCE. Dow Chemical in Freeport, TX, produces TCE by the direct chlorination process. PPG Industries in Lake Charles, LA, uses the oxychlorination process.

TABLE 2-1. TRICHLOROETHYLENE PRODUCTION PLANTS

Company	Location	Process	Capacity[a] (Mg/Yr) (1984)
Dow Chemical, USA	Freeport, TX	Chlorination of Ethylene Dichloride	54,600
PPG Industries, Inc.	Lake Charles, LA	Oxychlorination of Ethylene Dichloride	100,000

[a] Estimated capacities from Mannsville Chemical Products Corporation.

2.2.1 Chlorination of Ethylene Dichloride (EDC)

The chlorination of EDC accounts for approximately 35 percent of the current TCE production capacity.[1] At present, only one plant, Dow Chemical in Freeport, TX, uses this process. Perchloroethylene is the major coproduct of this reaction.

2.2.1.1 Process Description.[3] Trichloroethylene and perchloroethylene (PCE) are co-produced from the chlorination of ethylene dichloride (EDC). Changes in the EDC/chlorine ratio determine which compound will be formed in the greatest quantity. The chlorination occurs according to the non-catalytic reaction:

$$\underset{\text{(EDC)}}{\mathrm{ClCH_2CH_2Cl}} + \underset{\text{(chlorine)}}{\mathrm{Cl_2}} \xrightarrow{400\text{-}450^\circ\mathrm{C}} \underset{\text{(TCE)}}{\mathrm{C_2HCl_3}} + \underset{\substack{\text{(hydrogen}\\\text{chloride)}}}{\mathrm{HCl}} + \underset{\text{(PCE)}}{\mathrm{[C_2H_3Cl]}}$$

The reaction is usually carried out at about 400° to 450°C (750° to 850°F) and at a pressure slightly above one atmosphere. A generalized process flow diagram is shown in Figure 2-1.

2.2.1.2 Current Emissions and Controls.[4] The major sources of emissions from this process at the Dow/Freeport facility are from storage tanks, equipment leaks, and handling operations. Emissions from process vents, equipment openings, and secondary sources were also reported. The emission types and quantity of emissions are shown in Table 2-2. The emission types and their controls are discussed below and are listed in Table 2-3.

The production of TCE resulted in total TCE emissions of 46.7 Mg at this facility in 1983. Equipment leaks accounted for a majority of these emissions, totalling 24.1 Mg (52 percent). The largest sources of equipment leaks were valves (11.8 Mg, 49 percent of equipment leak emissions) and pump seals (6.6 Mg, 27 percent of equipment leak emissions). Dow indicated that "containment and immediate pickup" procedures are practiced to control fugitive emissions.

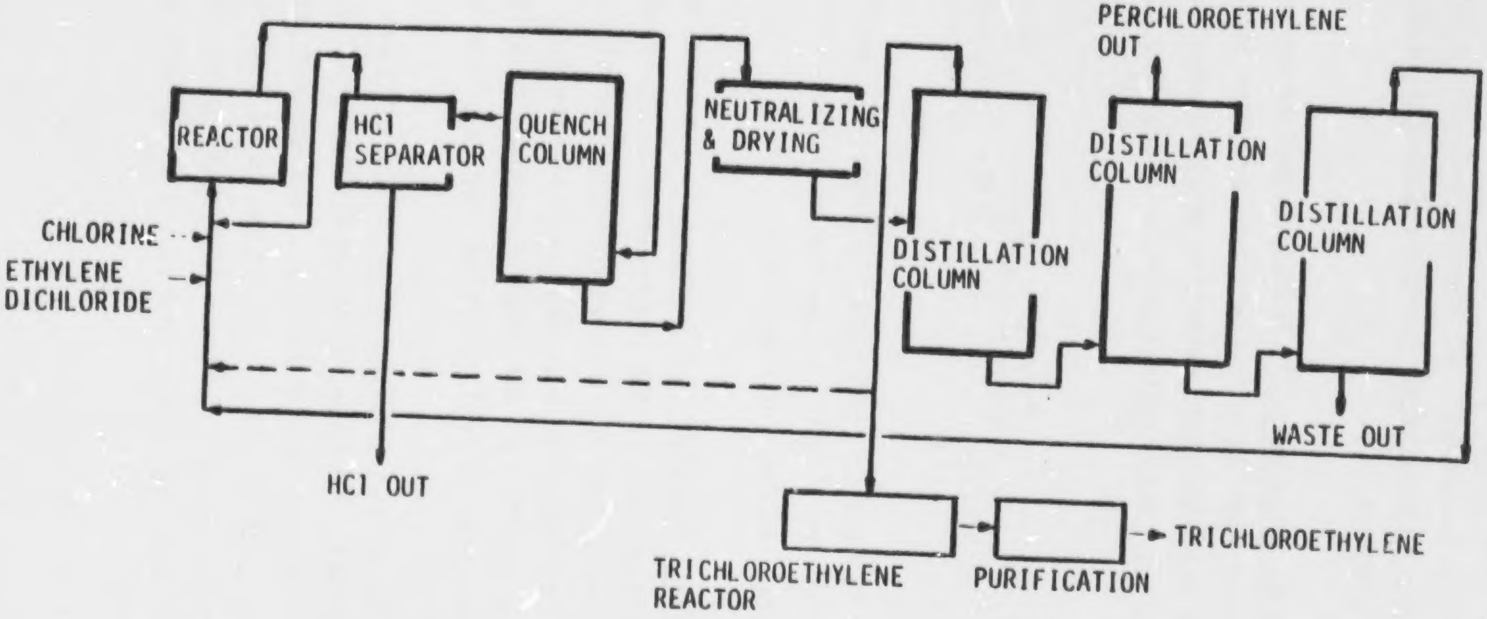

REACTOR
HCl SEPARATOR
QUENCH COLUMN
NEUTRALIZING & DRYING
DISTILLATION COLUMN
PERCHLOROETHYLENE OUT
DISTILLATION COLUMN
DISTILLATION COLUMN
CHLORINE
ETHYLENE DICHLORIDE
HCl OUT
WASTE OUT
TRICHLOROETHYLENE REACTOR
PURIFICATION
TRICHLOROETHYLENE

Figure 2-1. Process flow diagram for the production of trichloroethylene by direct chlorination.

TABLE 2-2. TOTAL EMISSIONS FROM TRICHLOROETHYLENE PRODUCTION PLANTS

			1983 Trichloroethylene Emissions (Mg/Yr)					
Plant/Location	Process	Equipment Leaks[a]	Relief Devices	Storage[b]	Handling	Equipment Openings	Secondary	Total
Dow Chemical, USA Freepor[illegible], TX	0.2	24.1	-	12.2	10.0	0.2	0.01	46.7
PPG Industries Lake Charles, LA	2.1	32.1	0.003	2.5	5.4	2.8	7.1	53.0
TOTAL	2.3	56.2	0.003	15.7	15.4	3.0	7.1	99.7

[a] Based on equipment count provided by plants and SOCMI equipment leak emission factors.

[b] Based on storage tank information provided by plants and AP-42 equations.

TABLE 2-3. CURRENT ESTIMATED EMISSIONS AND CONTROLS AT THE FACILITY PRODUCING TRICHLOROETHYLENE BY THE CHLORINATION OF EDC

Company/Location	Production Process	Type Of Emission	Present Controls	Reported Control Efficiency (%)	1984 TCE Emissions (Mg/yr)	Comments
Dow Chemical, USA Freeport, TX	Chlorination of Ethylene Dichloride	Process Vents	*	*	0.06	
			None	0	0.14	
		Equipment Leak	*	*	24.1	
		Equip. Op.	None	0	0.2	
		Storage	*	*	0.96	
			*	*	1.11	
			*	*	0.97	
			*	*	0.72	
			*	*	0.10	
			*	*	4.76	
			*	*	3.6	
		Handling	None	0	10	Trucks, tank cars, barges, ships
		Secondary	None	0	0.002	
			None	0	0.005	
			None	0	0.005	

* - Confidential.

The Texas Air Control Board has recently promulgated regulations that will require a formal equipment leak monitoring program. The first round of monitoring must be completed by the end of 1987. The regulation will require the annual testing of all valves in VOC service with a portable hydrocarbon analyzer, capping of open-ended lines and valves, monitoring of pump seals, and detailed recordkeeping of these practices.

Approximately 12.2 Mg of TCE (26 percent of total plant TCE emissions) were emitted from seven storage tanks at this facility in 1983. Storage tanks in Freeport (Brazoria County) having capacities greater than 25,000 gallons and storing liquids with a true vapor pressure greater than 1.5 psia are required to have vapor recovery systems or fully equipped internal or external floating roofs. The true vapor pressure of TCE is 1.5 psia at 80°F. Dow claimed that further information regarding its storage tanks is confidential.

Two process vents emitted approximately 0.2 Mg of TCE in 1983 (less than one percent of total plant emissions). One of the vents is located on a distillation column. This vent is uncontrolled and accounted for 70 percent of the process vent emissions from the plant. Dow claimed that further information regarding the process vents is confidential. Brazoria County regulations require that TCE emissions from vent streams must be burned properly at a temperature equal to or greater than 1300°F (704°C) in a smokeless flare or direct flame incinerator. Process vents are exempt from this regulation if they emit less than 45 kg per day and less than 110 kg per hour averaged over any 24-hour period.

TCE losses due to handling operations in 1983 were approximately 10 Mg, or 21 percent of the total emissions from the plant. Dow reported that products are loaded into tank trucks, rail cars, drums, barges, and ships. The trucks are reported to be bottom loaded with open domes. The rail cars are bottom or top dip-tube loaded with open vents. Barges and ships are loaded through top domes with open vents. Texas law states that facilities with an average daily throughput of 20,000 gallons (30-day average) must have controls on their loading and unloading operations. Dow did not report any controls on their handling operations.

Dow estimated that 0.01 Mg of TCE were emitted from secondary sources. Three sources, two waste streams from a landfill and one waste stream from a steam stripper, are reported as emitting TCE. No controls were reported for these streams. In addition, Dow reported that 0.2 Mg/yr of TCE was emitted due to 83 equipment openings. There are no laws specifically regulating secondary or equipment opening emissions in Brazoria County, TX.

2.2.2 Oxychlorination of Ethylene Dichloride (EDC)

The oxychlorination of EDC accounts for approximately 65 percent of the current TCE production capacity.[1] At present, only one plant, PPG Industries in Lake Charles, LA, uses this process.

2.2.2.1 Process Description.[5] PPG Industries developed this process and is currently the only company that uses the process to produce TCE.

This process, like the chlorination process, produces both TCE and perchloroethylene (PCE). The product mix can be varied by adjusting the EDC to chlorine ratio. The reaction for TCE is shown below:

$$\underset{\text{(EDC)}}{CH_2ClCH_2Cl} + Cl_2\text{/or } HCl + O_2 \xrightarrow{430^\circ C} \underset{\text{(TCE)}}{C_2HCl_3} + H_2O + \underset{\text{(PCE)}}{[C_2Cl_4]}$$

The build-up of a great amount of hydrogen chloride is avoided by concomitantly-operating HCl oxidation. The reaction involves simultaneous oxychlorination/dehydrochlorination with chlorine or anhydrous hydrogen chloride as the chlorine source. A typical process flow diagram is shown in Figure 2-2.

2.2.2.2 Current Emissions and Controls.[6] The major sources of emissions at this facility were equipment leaks and secondary sources. TCE emissions from process vents, storage tanks, equipment openings, handling operations, and relief device discharges were also reported. The emission types and quantities of emissions are shown in Table 2-2. The emission types and their controls are discussed below and are listed in Table 2-4.

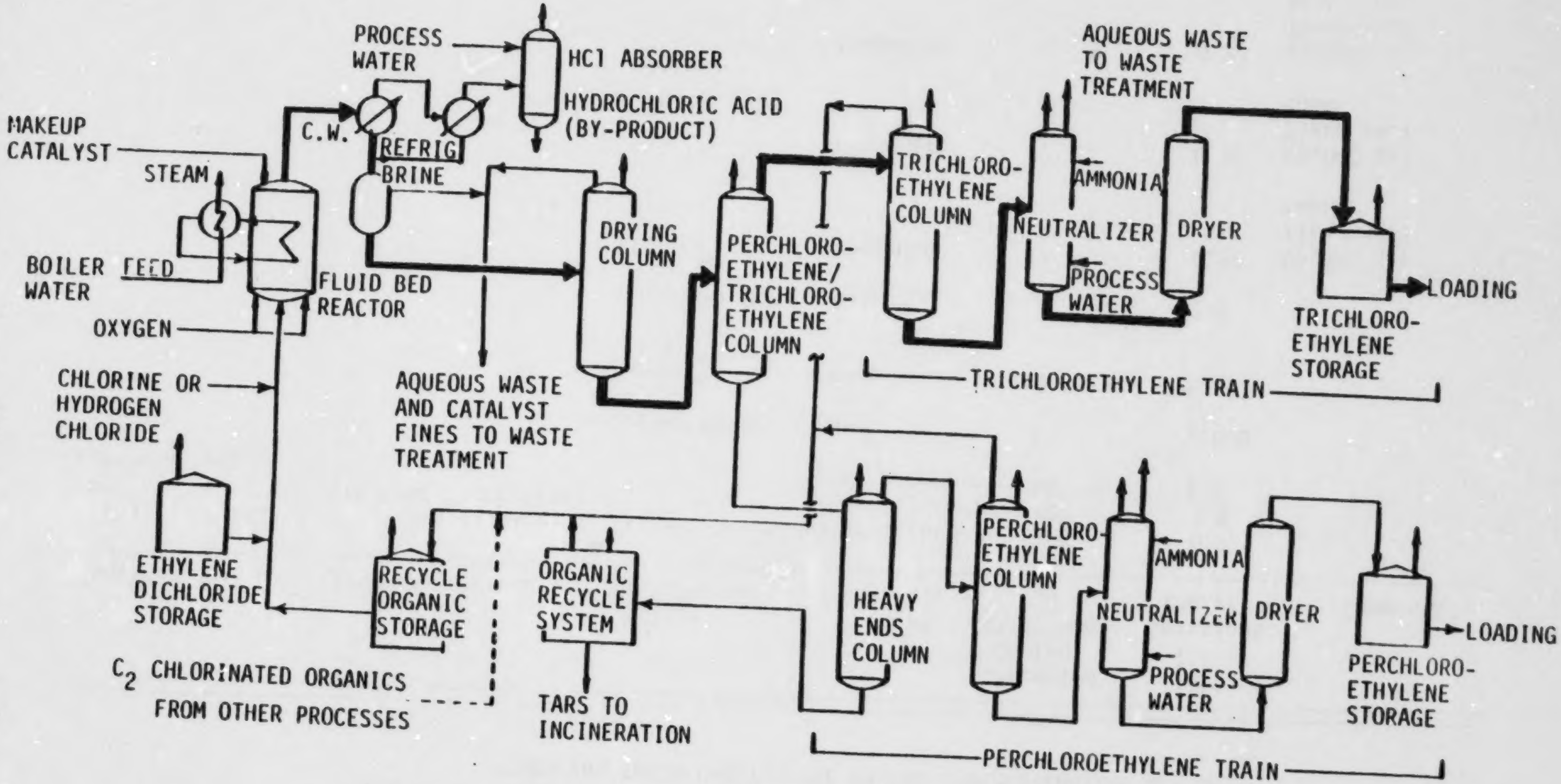

PROCESS WATER
HCl ABSORBER
HYDROCHLORIC ACID (BY-PRODUCT)
AQUEOUS WASTE TO WASTE TREATMENT
MAKEUP CATALYST
C.W.
REFRIG
BRINE
STEAM
BOILER FEED WATER
FLUID BED REACTOR
OXYGEN
DRYING COLUMN
PERCHLORO-ETHYLENE/ TRICHLORO-ETHYLENE COLUMN
TRICHLORO-ETHYLENE COLUMN
AMMONIA
NEUTRALIZER
PROCESS WATER
DRYER
LOADING
TRICHLORO-ETHYLENE STORAGE
TRICHLOROETHYLENE TRAIN
CHLORINE OR HYDROGEN CHLORIDE
AQUEOUS WASTE AND CATALYST FINES TO WASTE TREATMENT
ETHYLENE DICHLORIDE STORAGE
RECYCLE ORGANIC STORAGE
ORGANIC RECYCLE SYSTEM
HEAVY ENDS COLUMN
PERCHLORO-ETHYLENE COLUMN
AMMONIA
NEUTRALIZER
PROCESS WATER
DRYER
LOADING
PERCHLORO-ETHYLENE STORAGE
C_2 CHLORINATED ORGANICS FROM OTHER PROCESSES
TARS TO INCINERATION
PERCHLOROETHYLENE TRAIN

Figure 2-2. Process flow diagram for the production of trichloroethylene by oxychlorination.

TABLE 2-4. CURRENT ESTIMATED EMISSIONS AND CONTROLS AT THE FACILITY PRODUCING TRICHLOROETHYLENE BY THE OXYCHLORINATION OF EDC

Company/Location	Production Process	Type Of Emission	Present Controls	Reported Control Efficiency (%)	1983 TCE Emissions (Mg/yr)	Comments
PPG Industries, Inc. Lake Charles, LA	Oxychlorination of Ethylene Dichloride	Process Vents	Water Scrubber	ND[a]	0.1	
		-	Water Scrubber	ND[a]	0.5	
		-	Water Scrubber	ND[a]	1.5	
		Relief Device	None	0	.003	
		Equipment Leak	None	0	32.1	
		Equipment Op.	None	0	2.8	
		Storage	Condenser	77	0.37	65,000 gal fixed roof tank
			Condenser	77	0.37	65,000 gal fixed roof tank
			Condenser	77	0.37	65,000 gal fixed roof tank
			Condenser	77	0.033	13,500 gal fixed roof tank

TABLE 2-4. (Continued)

Company/Location	Production Process	Type Of Emission	Present Controls	Reported Control Efficiency (%)	1983 TCE Emissions (Mg/yr)	Comments
			Condenser	77	0.033	13,500 gal fixed roof tank
			Condenser	77	0.033	13,500 gal fixed roof tank
			Condenser	77	0.154	24,500 gal fixed roof tank
			Condenser	75	0.73	430,000 gal fixed roof tank
			Condenser	75	0.73	430,000 gal fixed roof tank
			Condenser	75	0.73	430,000 gal fixed roof tank
		Handling	None	0	5.4	
		Secondary	None	0[b]	7.1	

[a] No data provided.

[b] Assumed 0% control efficiency.

The production of TCE at the PPG facility resulted in total emissions of 53.0 Mg of TCE in 1983. Equipment leaks accounted for a majority of these emissions totalling 32.1 Mg/yr (60 percent of total plant emissions). The largest sources of equipment leaks were valves (16.4 Mg, 51 percent) and flanges (9.9 Mg, 31 percent). Eight pressure relief devices were controlled by rupture disks. PPG reported that there were no formal inspection programs used in 1983. Leaks were located by visual observations and repaired "promptly" for economic reasons (loss of product, corrosion of equipment). However, beginning in 1987 Louisiana regulations will require a VOC leak patrol/repair program. This includes annual monitoring of pump seals, pipeline valves in liquid service, and process drains, and quarterly monitoring of compressor seals, pipeline valves in gas service, and pressure relief valves.

TCE emissions from storage tanks at this facility in 1983 were 3.5 Mg (7 percent of total plant emissions). All ten storage tanks are equipped with fixed roofs. The tanks range in volume from 13,500 to 430,000 gallon and average 155,000 gallons. Storage tanks of these sizes containing TCE are required by Louisiana law to have a vapor recovery system. All ten tanks are controlled with condensers with reported efficiencies ranging from 75 to 77 percent.

Three process vents emitted approximately 2.1 Mg of TCE in 1983 (4 percent of total plant emissions). All three vents are controlled by water scrubbers with an unspecified control efficiency. One vent accounted for 72 percent of the process emissions. Louisiana requires process vent emissions greater than 91 Mg/yr to be controlled by incineration at 1,300°F with a 0.3 second residence time.

Losses occuring during handling operations in 1983 were approximately 5.4 Mg, or 10 percent of the total plant's TCE emission. PPG reported that TCE is transported by tank trucks, rail cars, barges, and ships. All of these operations are controlled by submerged fill pipe technology. Drums without controls are also used to handle a small amount of TCE. Louisiana law requires that all loading vehicles with a capacity of 200 gallons and a throughput of 40,000 gallons per day must have controls similar to submerged fill pipes.

PPG estimated that 7.1 Mg of TCE (13 percent of total plant emissions) were emitted from secondary sources. No controls were reported for the two secondary streams. In addition, PPG reported that 2.8 Mg (5 percent) of TCE were emitted due to 37 equipment openings. There are no laws specifically regulating secondary or equipment opening emissions in Louisiana.

2.3 COST OF ADDITIONAL CONTROLS

Cost estimates were developed for controlling emissions at TCE production facilities for sources that are not presently well controlled. The cost effectiveness of control was calculated for process vents, equipment leaks, storage tanks, and loading/handling operations. The details of the methods used for costing are presented in Appendix C. Table 2-5 summarizes the cost of additional control at TCE production facilities. The achievable TCE emission reduction for different VOC cost effectiveness ranges is presented in Table 2-6.

2.3.1 Control of Process Vent Emissions

The cost for additional control of process vent emissions was calculated for those vent streams that are not currently controlled to at least 98 percent efficiency. The cost for additional control is based on thermal incineration at 98 weight percent efficiency. The cost effectiveness values are $3.1 million/Mg VOC for the uncontrolled vent at the Dow facility and $2.4 million/Mg VOC for the three vents at the PPG facility. The potential TCE emission reductions for the Dow and PPG facilities are 0.13 and 0.19 Mg, respectively.

2.3.2 Control of Equipment Leak Emissions

Neither Dow nor PPG currently have formal programs to control equipment leak emissions. The costs for additional control of equipment leak emissions were estimated based on the requirements of the benzene fugitive NESHAP and the equipment count data supplied by Dow and PPG. For the Dow facility, the average control efficiency associated with controlling equipment leak was

TABLE 2-5. COST OF ADDITIONAL CONTROLS AT TCE PRODUCTION FACILITIES (1984 dollars)

Company/Location	Emission Type	Control	Control Efficiency (%)	TCE/VOC Emission Reduction (Mg/yr)	Capital Cost $(10^3\$)$	Recovery Credit $(10^3\$)$	Annual Cost $(10^3\$)$	Cost Effectiveness TCE ($/Mg)	Cost Effectiveness VOC ($/Mg)
Dow/Freeport, TX	Process	Incineration	98	0.13/0.13	980	0.0	410	3,038,000	3,038,000
	Equipment Leak	Leak detection & repair & equipment control	66	15.9/26.2	44	10	19	1,200	740
	Storage	FR-PO[a]	94	0.9/0.9	47	0.4	12	13,200	13,200
		FR-PO[a]	94	1.0/1.0	47	0.5	12	11,400	11,400
		FR-PO[a]	94	0.9/0.9	47	0.4	12	13,100	13,100
		FR-PO[a]	94	0.7/0.7	17	0.3	4	6,000	6,000
		FR-PO[a]	94	4.5/4.5	98	2.0	24	5,300	5,300
		FR-PO[a]	94	3.4/3.4	88	1.5	22	6,400	6,400
		FR-PO[a]	94	0.1/0.1	12	0.0	3	31,100	31,100
	Loading	Condenser	90	9.0/9.0	380	4.0	102	18,200	18,200
PPG/Lake Charles, LA	Process	Incineration	98	0.19/0.19	1,400	6.4	460	2,421,000	2,421,000
	Equipment Leak	Leak detection & repair & equipment control	44	14.1/20.2	31	8	16	1,100	780
	Storage	FR-PO[a]	94	1.0/1.0	71	0.5	18	17,500	17,500
		FR-PO[a]	94	0.1/0.1	46	0.0	12	130,000	130,000
		FR-PO[a]	94	0.1/0.1	16	0.1	4	27,800	27,800
		FR-PO[a]	94	0.7/0.7	52	0.3	13	19,600	19,600
	Loading	Condenser	90	4.8/4.8	380	2.1	103	34,300	34,300

[a] Floating roof tank with primary seal only.

TABLE 2-6. ESTIMATED TCE EMISSION REDUCTIONS AT TCE PRODUCTION FACILITIES

Cost Effectiveness Range ($/Mg)	Nationwide C_2HCl_3 Emission Reduction (Mg/yr)				
	Process	Equipment Leak	Storage	Loading	Total
Credit	-	-	-	-	-
0 - 500	-	-	-	-	-
500 - 1,000	-	30.0	-	-	30.0
1,000 - 2,000	-	-	-	-	-
2,000 - 5,000	-	-	-	-	-
>5,000	0.3	-	13.4	13.8	27.5
TOTAL	0.3	30.0	13.4	13.8	57.5

66 percent. The potential TCE emission reduction is estimated to be 15.9 Mg with an associated cost effectiveness of $740/Mg VOC. For the PPG facility, the average control efficiency associated with controlling equipment leaks was 44 percent. The potential TCE emission reduction is estimated to be 14.1 Mg with an estimated cost effectiveness of $780/Mg VOC.

2.3.3 Control of Storage Emissions

Costs for controlling all fixed-roof storage tanks containing TCE were estimated using three techniques: installation of internal floating roofs with primary seals only, the installation of internal floating roofs with primary and secondary seals, and a refrigerated condenser system. The control technique presented in Table 2-5 is the most cost effective technique. TCE emissions from all storage tanks can be reduced by 11.5 Mg at the Dow facility and 1.9 Mg at the PPG facility. The cost effectiveness of storage emission control was estimated to range from $5,300/Mg VOC for a storage tank at the Dow facility to $130,000/Mg VOC for a storage tank at the PPG facility.

2.3.4 Control of Loading Emissions

Loading emissions are not currently controlled at the Dow and PPG production facilities. Control costs for tank trucks, ships, barges, railcars, and drum were estimated using a condenser (90 percent efficient) as the control device. The cost effectiveness of loading emissions was estimated to be $18,200/Mg VOC at the Dow facility and $34,300/Mg VOC at the PPG plant. The potential TCE emission reduction is 9.0 Mg for the Dow facility and 4.8 Mg for the PPG facility.

2.4 REFERENCES

1. Mannsville Chemical Products. Chemical Products Synopsis - Trichloroethylene. Cortland, New York. 1984.

2. Letter from Morgan, D.L., Cleary, Gottlieb, Steen and Hamilton, to Rosensteel, R.E., EPA. February 22, 1985. Response for Halogenated Solvents Industry Alliance concerning industrial consumption volumes of trichloroethylene in 1983.

3. Misenheimer, D. C., and W. H. Battye (GCA Corporation). Locating and Estimating Air Emissions from Sources of Ethylene Dichloride. Prepared for U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication No. GCA-TR-CH-82-4. (Revised) February 1983. p. 5.

4. Letter and attachments from Arnold, S. W., Dow Chemical, U.S.A. to Farmer, J. R., EPA:ESED. February 28, 1985. Response to C_2HCl_3 114 Questionnaire.

5. SRI International. Assessment of Human Exposures to Atmospheric Perchloroethylene. Prepared for U.S. Environmental Protection Agency. Project No. CRU-6780. January 1979.

6. Letter and attachments from Komoroski, K. S., PPG Industries, Inc., to Farmer, J. R., EPA:ESED. February 14, 1985. Response to C_2HCl_3 Questionnaire.

3.0 OTHER CHEMICAL PRODUCTION PLANTS

This chapter presents the emissions and controls for six additional chemical plants reporting trichloroethylene (TCE) emissions. TCE was reported to be emitted at four plants where it is either produced as a by-product or used as a raw material. These processes include ethylene dichloride/vinyl chloride monomer manufacture (2 plants), polyvinyl chloride manufacture (1 plant), and vinylidene chloride manufacture (1 plant). TCE emissions from these four plants are from process vents, storage tanks, equipment openings, equipment leaks, handling operations, relief device discharges, and secondary (disposal) sources. TCE was also reported to be emitted at two other facilities which produce chlorinated solvents other than TCE. In order to offer a complete line of chlorinated solvents to their customers, these plants store TCE at their facilities, resulting in emissions from storage tanks, equipment leaks, and handling operations.

3.1 PROCESS DESCRIPTIONS, EMISSIONS, AND CURRENT CONTROLS

This section presents the emission estimates and current controls for other chemical plants reporting TCE emissions. TCE emissions come from the following processes: ethylene dichloride/vinyl chloride manufacture, polyvinyl chloride manufacture, vinylidene chloride manufacture, and storage to maintain a complete line of solvents.

3.1.1 Ethylene Dichloride (EDC)/Vinyl Chloride Monomer (VCM) Manufacture

Two EDC/VCM manufacturing plants reported TCE emissions in 1983. These plants were Shell Oil Co. in Deer Park, TX, and Borden Chemical in Geismar, LA. It is suspected that 15 other EDC/VCM facilities using the same process as Shell and Borden may also emit TCE as a by-product. However, seven of these other facilities which were contacted had no record of TCE emissions.

3.1.1.1 Process Description. TCE is formed as a byproduct in the first step of a two-step reaction which is employed at the two facilities. EDC is manufactured either by the direct chlorination of ethylene or by the oxychlorination of ethylene. In both cases, TCE is formed as a byproduct as shown in the following reactions.

Direct chlorination of ethylene[1]

$$Cl_2 + \underset{\text{(ethylene)}}{C_2H_4} \xrightarrow[FeCl_3]{100^\circ C} \underset{\text{(EDC)}}{ClCH_2CH_2Cl} + \underset{\text{(TCE)}}{\left[C_2HCl_3\right]}$$

Oxychlorination of ethylene[2]

$$\underset{\text{(ethylene)}}{C_2H_4 + HCl + O_2} \longrightarrow \underset{\text{(EDC)}}{ClCH_2CH_2Cl} + H_2O + \underset{\text{(TCE)}}{\left[C_2HCl_3\right]}$$

The second step in both processes is the cracking (pyrolysis) of EDC into vinyl chloride monomer, which does not result in TCE formation.

3.1.1.2 Current Emissions and Controls. The primary types of emissions from the two EDC/VCM facilities are from storage tanks, process vents, handling operations, and secondary sources. The types and quantities of emissions from these facilities are listed in Table 3-1. Emission estimates are also included in Table 3-1 for the 15 other EDC plants where TCE is suspected to be emitted as a by-product. No data were obtained directly from these other EDC plants. Emissions were estimated to be proportional to the emissions from the Shell and Borden EDC facilities that reported TCE emissions. The total TCE emissions from these other EDC plants are estimated to be 21 Mg/yr.

Shell Oil Co., Deer Park, TX[3]

The major source of TCE emissions for the Shell plant facility in 1983 was a fixed-roof storage tank. Shell also reported TCE emissions from process vents, handling operations, and a secondary source. The emission types and their controls are listed in Table 3-2.

TABLE 3-1. TOTAL EMISSIONS FROM OTHER CHEMICAL PRODUCTION FACILITIES

Plant/Location	Process	Equipment Leaks[a]	1983 Trichloroethylene Emissions (Mg/Yr) Relief Devices	Storage[b]	Handling	Equipment Openings	Secondary	Total
Shell Oil Deer Park, TX	3×10^{-4}	-	-	0.1	5×10^{-3}	-	0.02	0.1
Borden Chemical Geismar, LA	-	-	-	5×10^{-6}	-	-	-	5×10^{-6}
Other EDC Plants								21
Borden Chemical/ Illiopolis, IN	-	0.5	7×10^{-3}	0.02	-	6×10^{-3}	0.6	1.1
Dow Chemical/ Freeport, TX	1×10^{-7}	2.3	-	4×10^{-6}	-	-	-	2.3
Vulcan Chemicals/ Geismar, LA	-	-	-	1.1	0.9	-	-	2.0
Vulcan Chemicals/ Witchita, KS	-	0.9	-	0.5	0.2	-	-	1.6
TOTAL	3×10^{-4}	3.7	7×10^{-3}	1.7	1.1	6×10^{-3}	0.6	28.1

TABLE 3-2. CURRENT ESTIMATED EMISSIONS AND CONTROLS AT FACILITIES USING TRICHLOROETHYLENE

Company/ Location	Production Process	Type of Emission	Present Controls	Reported Control Efficiency (Percent)	1983 TCE Emissions (Mg/yr)	Comments
Shell Oil Co. Deer Park, TX	Vinyl Chloride Manufacture	Process	Organic Chloride Incinerator	98^b	1.5×10^{-4}	
			Organic Chloride Incinerator	98^b	1.5×10^{-4}	
		Storage	Compressor & Incinerator (C&I)	98^b	6×10^{-4}	376,000 gal fixed-roof tank
			C&I	98^b	9×10^{-5}	376,000 gal fixed-roof tank
			C&I	98^b	2×10^{-4}	376,000 gal fixed-roof tank
			C&I	98^b	2×10^{-4}	376,000 gal fixed-roof tank
			C&I	98^b	4×10^{-5}	282,000 gal fixed-roof tank

TABLE 3-2. (Continued)

Company/ Location	Production Process	Type of Emission	Present Controls	Reported Control Efficiency (Percent)	1983 TCE Emissions (Mg/yr)	Comments
			C&I	98^b	3×10^{-5}	424,000 gal fixed-roof tank
			None	0	0.1	56,000 gal fixed-roof tank
		Handling	None	0	5×10^{-3}	Tank trucks
		Secondary	None	0	0.02	
Borden Chemical Illiopolis, IL	PVC Manufacture	Process	Incinerator	98^b	ND^a	Emissions not reported
		Equipment Leaks	None	0	0.5	Rupture disks on relief valves
		Equip. Op.	None	0	6×10^{-3}	
		Storage	None	0	0.02	One 5,800 gal fixed-roof tank
		Secondary	None	0	0.6	
		Relief Dev Discharge	None	0	7×10^{-3}	From reactor over pressure

TABLE 3-2. (Continued)

Company/ Location	Production Process	Type of Emission	Present Controls	Reported Control Efficiency (Percent)	1983 TCE Emissions (Mg/yr)	Comments
Borden Chemical Geismar, LA	EDC Manufacture	Storage	Incinerator	98[b]	5×10^{-6}	4 - 300,000 gal. tanks
Dow Chemical, U.S.A. Freeport, TX	Vinylidene Chloride Production	Process	*	*	1×10^{-7}	One vent
		Equipment Leaks	None	0	2.3	
		Storage	*	*	4×10^{-6}	One pressure vessel
Vulcan Chemicals Geismar, LA	Chlorinated Methanes	Storage	*	*	1.1	One fixed-roof tank
		Handling	*	*	0.9	
Vulcan Chemicals Witchita, KA	Chlorinated Methanes	Equipment Leaks	None	0	0.9	
		Storage	*	*	0.5	One pressure vessel
		Handling	*	*	0.2	

---

[a] No data reported.

[b] Control efficiency reported by company is greater than 98 percent. Only 98 percent efficiency is accepted if sampling data are not provided.

*Company implies this information to be confidential.

The production of EDC by the direct chlorination of ethylene resulted in total TCE emissions of slightly more than 0.1 Mg in 1983 at this facility. Storage tanks accounted for a majority of these emissions, totalling about 0.1 Mg (79 percent of the plant emissions). Of the seven storage tanks at this facility, one 56,000 gallon tank contributed 99 percent of TCE storage emissions. This tank is not reported to have any control technique associated with it. The other six tanks were controlled by a compression and incineration system that has a reported control efficiency of greater than 98 percent. The Texas State regulations require that storage tanks containing certain VOC classes (including TCE) and with a volume greater than 40,000 gallons must be controlled by an internal floating roof tank, an external floating roof tank with a vapor mounted primary and secondary seal, or a vapor recovery system.

Secondary emissions from a waste stream accounted for 0.02 Mg of TCE emissions (16 percent). Texas regulations do not require any control for streams of this kind.

Two process vents, which are controlled by an incinerator with a reported efficiency of greater than 98 percent, result in less than one percent of the total plant emissions (3×10^{-4} Mg/yr). These process vents are controlled through incineration because of the vinyl chloride NESHAP which requires streams containing vinyl chloride to be controlled to less than 10 ppm VCM. In addition, process vent emissions in Deer Park (Harris County) are regulated by the State. These regulations require process vent gas streams containing certain VOC classes (including TCE) to be incinerated properly at a temperature equal to or greater than 1300°F (704°C) in a smokeless flare or a direct flame incinerator before they are allowed to enter the atmosphere.

Tank trucks, which receive the heavy ends from the EDC distillation step of the process, account for 5×10^{-3} Mg (4 percent) of TCE emissions. Shell reported that a vapor recovery system is not used in their handling operations. Texas law states that facilities with an average daily throughput of 20,000 gallons (30-day average) must have controls on loading and unloading operations.

Borden Chemical, Geismar, LA[4]

The only reported source of TCE emissions from this facility is storage tanks. The tanks are reported to be controlled by an incinerator with an efficiency of greater than 98 percent. This facility produces EDC by the oxychlorination process and stores the EDC, contaminated by TCE at approximately 0.1 percent, in four 300,000 gallon tanks. The emissions from these tanks totalled 5×10^{-6} Mg in 1983.

3.1.2 Polyvinyl chloride (PVC) Manufacture

Borden Chemical in Illiopolis, IL, was the only PVC production facility reporting TCE emissions in 1983. It was not within the scope of this study to contact all the PVC producers regarding their emissions of TCE. Thus, detailed emissions information for PVC production was not obtained. However, other EPA studies have indicated significant use of TCE as a reaction chain terminator in the production of PVC. Chapter 7 presents the consumption and emission estimates for TCE in PVC production.

3.1.2.1 Process Description.[4] Borden reported that vinyl chloride, vinyl acetate, and water are the primary raw materials used to manufacture the PVC co-polymer. They also reported that TCE is used as a secondary raw material and is present in quantities of less than 91 kg per batch. A reaction equation for the process follows:

$$\underset{\text{(vinyl chloride)}}{C_2H_3Cl} + \underset{\text{(vinyl acetate)}}{C_2HCHOCOC_3H} + H_2O + \underset{\text{(TCE)}}{C_2HCl_3} \longrightarrow$$

$$\underset{\text{(PVC)}}{[-CH_2CHCl : CH_2CHCl : CH_2CHCl-]_n}$$

3.1.2.2 Current Emissions and Controls.[4] The major emissions from this process at the Borden/Illiopolis facility are from equipment leaks and secondary sources. TCE was also emitted from equipment openings, storage tanks and relief device. The emission types and quantities are presented in Table 3-1.

The production of PVC resulted in emissions of about 1.1 Mg of TCE in 1983 at this facility. Equipment leaks accounted for 0.5 Mg (45 percent) of TCE emissions in 1983. The major equipment leaks were valves (0.1 Mg, 20 percent of equipment leak emissions), open end lines (0.3 Mg, 60 percent), and flanges (0.04 Mg, 8 percent). Illinois does not regulate VOC emissions from equipment leaks.

The final effluent from a quench tank waste stream was estimated to result in 0.6 Mg (55 percent of plant total) of TCE. Illinois does not regulate VOC emissions from secondary sources.

Two equipment openings released 6×10^{-3} Mg of TCE (less than one percent of total plant emissions) in 1983. Two pressure relief device discharges resulted in TCE emissions of 7×10^{-3} Mg (less than one percent) in 1983. Borden also reported that a process vent was controlled with an incinerator and a quench tank system with a reported control efficiency of greater than 98 percent. However, emissions were not reported for this process vent. Illinois regulations require process vent emissions of organic compounds to be limited to 100 ppm equivalent methane.

One fixed roof 5,800 gallon storage tank emitted 0.02 Mg (2 percent) of TCE in 1983. For organic compound storage tanks with volumes over 40,000 gallons, Illinois regulations require that (1) the tank must be a pressure vessel, (2) the tank must be equipped with a floating roof, or (3) an 85 percent efficient vapor recovery system must be in place.

3.1.3 Vinylidene Chloride Manufacture

Dow Chemical's Freeport, TX, plant was the only vinylidene chloride manufacturing facility that reported TCE emissions in 1983.

3.1.3.1 Process Description.[5] TCE is formed as a byproduct in the manufacture of vinylidene chloride. Vinylidene chloride may be made by the action of caustic on 1,1,2-trichoroethane, as is shown in the following equation:

$$\underset{\text{(1,1,2-trichloroethane)}}{CH_2ClCHCl_2} + NaOH \xrightarrow{\text{water}} \underset{\text{(vinyldene chloride)}}{CCl_2CH_2} + H_2O + NaCl + \underset{\text{(TCE)}}{\left[C_2HCl_3\right]}$$

The TCE is separated from the reaction mass in a distillation column. TCE is also present in the final product stream and in an exhaust stream that is vented to the atmosphere.

3.1.3.2 Current Emissions and Controls.[5] The major source of TCE emissions from the Dow facility is equipment leaks. TCE emissions from a process vent and a storage tank were also reported. The emission types and quantities are presented in Table 3-1. The emissions types and their controls are listed in Table 3-2. The production of vinylidene chloride at this facility resulted in about 2.3 Mg of TCE emissions in 1983. Equipment leaks accounted for nearly 100 percent of this total. Valves were the major source of equipment leaks (1.3 Mg, 57 percent of all leaks) while flanges were also a significant contributor (0.6 Mg, 26 percent). Dow reported that the plant has a monitoring system that detects between 75 and 80 percent of all leaks. No information was provided on the frequency of repair for detected leaks. Therefore, equipment leak emissions estimates are based on uncontrolled emission factors.

The Texas Air Control Board has recently promulgated regulations that will require a formal equipment leak monitoring program. The first round of monitoring must be completed by the end of 1987. The regulation will require the annual testing of all valves in VOC service with a portable hydrocarbon analyzer, the capping of open-ended lines and valves, the monitoring of pump seals, and the detailed recordkeeping of these practices.

TCE emissions from one process vent and one storage tank at this facility are estimated to be 4×10^{-6} Mg/yr. Dow considers further information regarding the process vent and storage tank to be confidential.

3.1.4 Storage of TCE for Resale[6]

Two Vulcan Chemicals plants in Geismar, LA and Wichita, KS, store TCE on-site for the purpose of resale to their chlorinated solvent customers. The company reported that TCE is not used as a feedstock or created as a byproduct at these facilities.

3.1.4.1 Current Emissions and Controls

Vulcan Chemicals, Geismar, LA[7]

The Vulcan Chemicals facility in Geismar, LA, reported that two sources of TCE emissions, storage tanks and handling operations, resulted in the emission of 2.0 Mg of TCE in 1983. The emission types and their controls are listed in Table 3-2.

One storage tank resulted in the emission of 1.1 Mg of TCE (55 percent of total plant emissions). Vulcan considers further information regarding their storage tanks to be confidential. Louisiana state regulations require storage tanks with volumes greater than 40,000 gallons which contain volatile organic compounds to meet certain specifications. The storage vessels must either be pressure tanks, be equipped with submerged fill pipes, or have floating roofs.

Handling operations accounted for the remaining 0.9 Mg (45 percent) of plant TCE emissions. The company claimed that the control techniques for reducing handling emissions are confidential. Louisiana state regulations require that any loading facility for VOC servicing tanks, trucks, or trailers having a capacity in excess of 200 gallons and having 20,000 gallons per day (gpd) throughput for new facilities or 40,000 gpd for existing facilities, averaged over any 30-day period, must be equipped with a vapor recovery and disposal system.

Vulcan Chemicals, Witchita, KS[8]

The Vulcan Chemicals facility in Witchita, KS, was estimated to have emitted 1.6 Mg of TCE in 1983. Equipment leaks accounted for 0.9 Mg of TCE emissions in 1983 (56 percent of total plant emissions). Pump seals were the major source of leaks (0.4 Mg, 45 percent of total equipment leaks). Flanges accounted for another 0.3 Mg (34 percent) of TCE equipment leaks emissions. Kansas state law does not regulate VOC emissions from equipment leaks.

One storage tank was estimated to have emitted 0.5 Mg (31 percent of total plant TCE emissions). Handling operations accounted for 0.2 Mg of TCE emissions (12 percent). Vulcan considers further information regarding storage tanks and handling operations to be confidential. Kansas does not have any laws regulating TCE emissions from storage tanks or from handling operations.

3.2 COST OF ADDITIONAL CONTROLS

Cost estimates were developed for controlling TCE emissions at the other chemical production plants for sources that are not presently well controlled. The cost effectiveness of control was calculated for equipment leaks, and storage emissions. Methods used for calculating these costs are presented in Appendix C. Table 3-3 summarizes the cost of additional control at these chemical plants and Table 3-4 presents potential emission reductions at various cost-effectiveness levels.

Table 3-4 indicates that further control of TCE emissions at these sources can result in reduction of 3.5 Mg/yr at cost-effectiveness values ranging from $1,900/Mg of VOC to $139,000/Mg of VOC. Process vents are reported to be well controlled and, thus, further controls are not costed. Of the total potential TCE emission reductions, emission reductions from equipment leaks account for 57 percent while additional emission reductions from storage tanks account for the remaining 43 percent.

3.2.1 Control of Equipment Leaks

The cost for additional control of equipment leaks were estimated based on the requirements of the benzene equipment leaks NESHAP and company supplied equipment counts.

TCE emissions can be reduced by 2.0 Mg by applying these controls. This would result in a 53 percent reduction in equipment leak emissions.

The cost effectiveness of controlling equipment leak emissions ranges from $1,900/Mg VOC at the Dow/Freeport facility to $17,800/Mg VOC at the Borden/Illiopolis facility.

TABLE 3-3. ESTIMATED COST OF ADDITIONAL CONTROL DEVICES AT OTHER CHEMICAL PRODUCTION FACILITIES

Company/Location	Emission Type	Control	Control Efficiency (%)	TCE/VOC Emission Reduction (Mg/yr)	Capital Cost (10^3 \$)	Recovery Credit (10^3 \$)	Net Annual Cost (10^3 \$)	Cost Effectiveness TCE (\$/Mg)	Cost Effectiveness VOC (\$/Mg)
Shell Oil Co./ Deer Park, TX	Storage	Floating roof/ Primary seal	94	0.1/0.5	23.4	0.0	6.1	62,600	12,500
Borden Chemical Co./ Illiopolis, IL	Storage	Floating roof/ Primary seal	94	<0.05/<0.05	10.7	0.0	2.8	139,000	139,000
	Equipment Leak	Leak detection & repair & equipment control	81	0.4/0.4	14.3	0.2	7.8	17,900	17,800
Dow Chemical, USA/ Freeport, TX	Equipment Leak	Leak detection & repair & equipment control	48	1.1/4.6	16.5	1.6	8.7	7,800	1,900
Vulcan Chemical Co./ Geismar, LA	Storage	Floating roof/ Primary seal	94	1.0/1.0	35.6	0.4	8.9	8,800	8,800
Vulcan Chemical Co./ Witchita, KS	Storage	Condenser	85	0.4/0.4	111	0.3	28.8	71,000	71,000
	Equipment Leak	Leak detection & repair & equipment control	49	0.5/1.3	13.7	0.5	7.6	16,700	5,900

TABLE 3-4. ESTIMATED TCE EMISSION REDUCTIONS FOR OTHER CHEMICAL PRODUCTION FACILITIES AS A FUNCTION OF COST EFFECTIVENESS

Cost Effectiveness Range ($/Mg VOC)	Nationwide TCE Emission Reduction (Mg/yr)			
	Process	Equipment Leak	Storage	Total
Credit	-	-	-	-
0 - 5,000	-	1.1	-	1.1
5,001 - 10,000	-	0.5	1.0	1.5
10,001 - 15,000	-	-	0.1	0.1
15,001 - 20,000	-	0.4	-	0.4
>20,001	-	-	0.4	0.4
TOTAL	0.0	2.0	1.5	3.5

3.2.2 Control of Storage Emissions

Costs for controlling emissions from fixed-roof storage tanks containing TCE were estimated using three control techniques: the installation of internal floating roofs with primary seals only, the installation of internal floating roofs with primary and secondary seals, and the installation of a refrigerated condenser. The control technique which yielded the lowest cost effectiveness ($/Mg VOC) for each facility is presented in Table 3-3.

TCE emissions can be reduced by 89 percent (1.5 Mg) by applying these controls. The cost effectiveness of controlling storage tank emissions ranges from $8,800/Mg at the Vulcan/Geismar facility to $139,000/Mg VOC at the Borden/Illiopolis facility.

3.3 REFERENCES

1. "Source Assessment: Chlorinated Hydrocarbons Manufacture", Kahn, Z. S., et al. Prepared for U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C. August 1979. p. 17. EPA-600/2-79-019g.

2. "Chemistry of Organic Compounds", Noller, Carl R. Saunders Publishing, Third Edition. p. 794.

3. Letter and attachments from Gillespie, T. E., Shell Chemical Company, to Farmer, J. R., EPA:ESED. January 4, 1985. Response to C_2HCl_3 114 Questionnaire.

4. Letter and attachments from Springer, C. R., Borden, Incorporated, to Farmer, J. R., EPA:ESED. February 15, 1985. Response to C_2HCl_3 114 Questionnaire.

5. Letter and attachments from Arnold, S. L., Dow Chemical, U.S.A., to Farmer, J. R., EPA:ESED. February 28, 1985. Response to C_2HCl_3 114 Questionnaire.

6. Letter and attachments from Boyd, J. M., Vulcan Chemicals, to Farmer, J. R., EPA:ESED. February 1, 1985. Response to C_2HCl_3 114 Questionnaire.

4.0 SOLVENT DEGREASING OPERATIONS

About eighty-five percent (or 56,000 Mg) of the total trichloroethylene (TCE) produced in 1983 was consumed as a solvent for degreasing operations. It is estimated that of this amount about 52,600 Mg were emitted to the atmosphere. Trichloroethylene was used as a solvent for degreasing in a variety of industries, primarily within five distinct Standard Industrial Classifications (SIC). Emissions from degreasing operations were estimated in this study by obtaining the 1983 consumption of TCE for each SIC and applying to it an emission factor derived for degreasing operations. The following sections present a brief discussion of the types of degreasers, emissions, emissions control, estimates of emissions from degreasing operations in 1983, and estimates of the costs associated with emissions control. Due to the large number of degreasing facilities in these industries, no attempt was made in this study to identify locations of individual degreasers.

4.1 INDUSTRY DESCRIPTION

Degreasing is an integral part of many industrial processes such as the manufacture of automobiles, electronics, furniture, appliances, jewelry, and plumbing fixtures. It is also used to a minor extent in the textiles, paper, plastics, and glass manufacturing industries. The degreasing process makes use of nonaqueous or aqueous solvents to clean and remove debris from a surface prior to painting, plating, assembly, repair, inspection, or other treatment. Various solvents, including petroleum distillates, chlorinated hydrocarbons, ketones, and alcohols are used either alone or in blends for degreasing purposes.[1] Five major industry groups used TCE in degreasing operations. These are furniture and fixtures (SIC 25), fabricated metal products (SIC 34), electric and electronic equipment (SIC 36), transportation equipment (SIC 37), and miscellaneous manufacturing industries (SIC 39).[2]

4.2 DEGREASING EQUIPMENT

There are three basic types of degreasing equipment: cold cleaners, open top vapor degreasers, and conveyorized degreasers. Cold cleaners are usually the simplest and least expensive type of degreaser. Simple cold cleaners consist of a tank of solvent with a cover for nonuse periods. More sophisticated cold cleaners may have solvent sumps, spray nozzles, drains, and automatic controls. In the typical cold cleaning process, soiled objects are dipped into the solvent bath until the soils are dissolved from the surface. The cleaning process can be enhanced by agitating the solvent and brushing or spraying soiled parts. Solvents are normally used at room temperature, but in some applications may be heated to a temperature below the boiling point of the solvent.[1]

Open top vapor degreasers are similar in configuration to cold cleaners but are operated in a different manner. Open top vapor degreasers are operated at an elevated temperature to boil the solvent. The vapors from the boiling solvent condense on and clean soiled objects. A typical open top vapor degreaser consists of a tank equipped with a heating and cooling system. The heating coils on the inside bottom of the tank boil the solvent, thereby generating the vapors needed for cleaning. Cooling coils located near the top and on the inside perimeter of the tank condense solvent vapors, preventing them from diffusing out of the tank. Thus, a controlled vapor zone is created within the tank. Soiled objects are lowered into the vapor zone where solvent condenses on their surfaces and dissolves the soils. When condensation ceases, the cleaned objects are withdrawn. Only halogenated solvents are used for vapor degreasing because, in addition to their excellent cleaning capabilities, they are nonflammable and because their heavy vapors can be easily contained within the machine.[1]

Conveyorized degreasers feature automated conveying systems for continuous cleaning of parts. Conveyorized degreasers clean either by cold cleaning or vapor degreasing, although most clean using vaporized solvent. While these units tend to be the largest degreasers, they are enclosed systems and actually produce less emissions per part cleaned than other types of degreasers.[1]

4.3 EMISSIONS FROM DEGREASING OPERATIONS

National emission estimates for degreasing operations were calculated from 1983 TCE consumption data provided by the (Halogenated Solvents Industry Alliance (HSIA).[2] The consumption data were used in conjunction with emission factors generated from available literature to estimate nationwide emissions.[1] A brief description of the estimation procedure follows.

Available data indicate that 5 percent of all TCE consumed in degreasing operations is used in cold cleaning while about 95 percent is used in vapor degreasing.[3] Previous EPA studies estimated that for every kg of a solvent used in cold degreasing, 0.43 kg are emitted. The corresponding emission factor for open top vapor degreasing is 0.785 kg/kg solvent consumed and for conveyorized degreasing is 0.85 kg/kg solvent consumed.[4] Assuming that vapor degreasing use of TCE is divided equally between open top and conveyorized degreasing processes, a weighted average emission factor of 0.79 kg/kg TCE consumed was calculated. It was assumed that the remaining 0.21 kg/kg TCE consumed would be recycled.

Based on information from solvent recyclers,[5] it was estimated that about 75 percent of all waste solvent from degreasing (0.21 kg/kg TCE consumed) is recovered and reused. Therefore, total TCE consumption by a degreaser equals consumption of fresh solvent plus consumption of recycled solvent. As before, 0.79 kg/kg of the recycled solvent is emitted. Taking into account the emission of recycled solvent, it is estimated that for every kg of fresh TCE used in degreasing, 0.94 kg is emitted. The remaining 0.06 kg is assumed to be either incinerated or disposed of in a landfill according to appropriate regulations. Appendix A presents the details of these material balance calculations.

The total 1983 TCE emissions for each of the five SICs were estimated by applying the 0.94 kg factor to the 1983 TCE consumption figure (56,000 Mg). Table 4-1 shows the estimated TCE emissions from degreasing operations in these industries.

TABLE 4-1. 1983 TCE EMISSIONS FROM DEGREASING OPERATIONS, BY INDUSTRY

Industry (SIC Code)	Emissions (Mg/yr)
Furniture and Fixtures (25)	4,370
Fabricated Products (34)	21,930
Electrical and Electronic Equipment (36)	9,140
Transportation Equipment (37)	10,730
Miscellaneous Manufacturing Industries (39)	6,430
TOTAL	52,600

Emissions were also estimated for each State in the U.S. The TCE emissions were estimated by assuming that emissions are proportional to the number of employees for a given industry in each State. The total number of employees in each of the five industry groups was estimated from U. S. Department of Commerce data.[6] For example, the emissions in Illinois from the fabricated products manufacturing industry (SIC 25) were estimated as follows:

- Furniture and fixtures manufacturing consumption of TCE in 1983 = 4,648 Mg.
- 4,648 Mg x 0.94 $\frac{\text{Mg emitted}}{\text{Mg consumed}}$ = 4,369 Mg emitted.
- The number of employees within the furniture and fixtures manufacturing industry for Illinois = 18,738.
- Total number of employees within the furniture and fixtures manufacturing industry = 437,530.
- Illinois emissions = 4,369 x $\frac{18,738}{437,530}$ = 190 Mg

This procedure was followed for each industry identified to use TCE in degreasing operations. The results are presented for each State in Table 4-2.

4.4 EMISSIONS CONTROL

Control methods specified in the CTG and BID for degreasing are summarized in Table 4-3.[1,7] These methods include add-on equipment as well as improved work practices.

Add-on equipment for control of degreaser emissions includes adding covers to degreaser openings, increasing freeboard area, adding freeboard chillers, and providing drainage racks for parts. These devices limit evaporation losses from solvent baths and solvent carry-out. More sophisticated control techniques include carbon adsorption to recover solvent vapors.

TABLE 4-2. 1983 TRICHLOROETHYLENE EMISSIONS FROM DEGREASING OPERATIONS, BY STATE

State	Emissions (Mg)	State	Emissions (Mg)
Alabama	750	Montana	15
Alaska	3	Nebraska	200
Arizona	470	Nevada	60
Arkansas	520	New Hampshire	200
California	6,100	New Jersey	1,700
Colorado	510	New Mexico	70
Connecticut	1,700	New York	3,430
Delaware	80	North Carolina	1,700
District of Columbia	7	North Dakota	20
Florida	1,400	Ohio	3,600
Georgia	880	Oklahoma	580
Hawaii	30	Oregon	250
Idaho	30	Pennsylvania	2,840
Illinois	3,350	Puerto Rico	250
Indiana	2,700	Rhode Island	700
Iowa	550	South Carolina	450
Kansas	490	South Dakota	30
Kentucky	600	Tennessee	1,160
Louisiana	550	Texas	2,250
Maine	170	Utah	250
Maryland	530	Vermont	150
Massachusetts	1,700	Virginia	1,000
Michigan	3,390	Washington	850
Minnesota	820	West Virginia	150
Mississippi	600	Wisconsin	1,330
Missouri	1,430	Wyoming	4
		TOTAL	52,600

TABLE 4-3. EXAMPLE CONTROL TECHNIQUES FOR DEGREASERS

Degreaser Type	Control Devices	Operating Practices
Cold Cleaners	Cover for tank Parts drainage rack Raised freeboard[a]	Keep cover closed when degreaser not in use Fully drain cleaned parts
Vapor Degreasers	Cover for tank Freeboard chiller[b] Raised freeboard Carbon adsorber	Keep cover closed when degreaser not in use Fully drain cleaned parts Move parts slowly into and out of degreaser
Conveyorized Degreasers	Port Covers Freeboard chillers Carbon adsorbers	Maintain conveyor at moderate speed Keep exhaust ventilation rates moderate

[a] Freeboard is the distance from the liquid solvent surface or top of the solvent vapor to the lip of the tank. "Raised freeboard" is a physical extension of the freeboard to reduce drafts, and thereby solvent evaporation, within the degreaser.

[b] Additional cooling coils above the primary coils to further inhibit the diffusion of solvent vapors to the atmosphere.

Work practices can be improved to limit solvent emissions from degreasing. These improvements, characterized by practices that reduce solvent exposure to the atmosphere, include: keeping degreaser covers closed, fully draining parts prior to removal from degreaser, maintaining moderate conveyor speeds, and keeping ventilation rates moderate.

4.5 COST OF EMISSIONS CONTROL

The costs for controlling emissions from model degreasing facilities have been estimated in previous EPA-sponsored studies.[7,8,9] The purpose of the cost evaluation effort for this document is to update the costs presented in the earlier EPA studies. Costs are presented for a representative size degreaser for each of three degreaser types: (1) cold cleaners, (2) open top vapor degreasers, and (3) conveyorized vapor degreasers. These cost estimates are for retrofitting existing degreasing facilities. Tables 4-4, 4-5, and 4-6 present the retrofit cost estimates for cold cleaners, open top vapor degreasers, and conveyorized vapor degreasers, respectively. The costs estimated in the previous EPA study are in fourth quarter 1980 dollars. These costs were updated to fourth quarter 1984 dollars using plant cost indexes (323.6/269.7 = 1.20).[10,11]

Several assumptions concerning degreaser operating parameters were made in developing costs for controlling emissions from the three types of degreasers. It was necessary to assume operating parameters for typical uncontrolled and controlled degreasers so that average emission reductions for each type of degreaser could be determined.

In developing cold cleaner control costs the degreaser size was assumed to be 0.4 m^2 and the annual period of operation was assumed to be 500 hours (2 hrs/day, 5 days/week, 50 weeks per year). The uncontrolled emissions were based on a cold cleaner with a 0.3 freeboard ratio and a manual cover. Total emissions from this uncontrolled cold cleaner were estimated to be 1,140 kg/yr. The controlled emissions were based on a cold cleaner with a 0.75 freeboard ratio, a manual cover, and a drainage rack. Total emissions from this cold cleaner were estimated to be 740 kg/yr. It is estimated that a 35 percent emissions reduction can be achieved with a raised freeboard, manual cover, and a drainage rack.[9,12,13]

TABLE 4-4. RETROFIT CONTROL COSTS FOR COLD CLEANERS (Fourth Quarter 1984 Dollars)

	0.7 FBR[a], Manual Cover, and Drain
Capital Costs, ($)	
- Freeboard (installed)	360
- Drain	25
Installation Costs, $	
- Freeboard (in purchase cost)	-
- Drain	13
Total Installed Capital Costs, $	398
Annual Operating Costs, #/yr	
- Capital Charges[b]	53
- Administration, Insurance, and Taxes[c]	16
- Operating Labor[d]	288
- Maintenance[e]	12
- Utilities	0
Total Annualized Cost, $/Yr	370
Emission Reduction, Mg/Yr	0.4
Recovered Solvent Credit[f], $/Yr	176
Net Annualized Cost, $/Yr	180
Cost Effectiveness, $/Mg	450

[a] Freeboard ratio.

[b] Total Installed Capital Cost annualized over 15 years at a 10 percent interest rate.

[c] Four percent of total installed capital cost.

[d] Labor due to drain time requirement, based on 20 loads per day, 15 second drain time per load.

[e] Three percent of total installed capital cost.

[f] Based on solvent price of $0.44 per kilogram.

TABLE 4-5. RETROFIT CONTROLS COSTS FOR OPEN TOP VAPOR DEGREASERS
(1984 Dollars)

	Cover 0.75 FBR[a]	Automatic Cover 0.75 FBR[a]	Cover Above Freezing FBC[b,c]	Cover Below Freezing FBC[c]	Cover, Carbon Adsorber
Capital Costs, $					
Cover	1,238	3,832	1,238	1,238	1,238
0.75 Freeboard	1,012	268	1,012	1,012	1,012
Refrig. Freeboard	-	-	-	-	-
Carbon Adsorber	-	-	-	-	-
Auxiliary Equipment	595	595	595	595	595
Added Plant Space	-	-	-	-	-
Installation Costs, $					
Cover	136	203	136	136	136
0.75 Freeboard	136	136	136	136	136
Refrig. Freeboard	-	-	217	217	-
Carbon Adsorber	-	-	-	-	5,950
Auxiliary Equipment	136	136	136	136	136
Total Installed Capital Costs, $	3,253	5,170	8,499	13,021	18,366
Annual Operating Costs, $/yr					
Capital Charges $/yr[d]	427	679	1,117	1,711	2,413
Administration, Ins., Taxes[e]	130	207	45	68	97
Maintenance[f]	98	155	34	51	72
Added Labor	570	-	570	570	570
Utilities					
Electricity	-	-	71	98	208
Steam	-	-	-	-	201
Water	-	-	-	-	26

TABLE 4-5. (Continued)

Cost Component	Cover 0.75 FBR[a]	Automatic Cover 0.75 FBR	Cover Above Freezing FBC[b,c]	Cover Below Freezing FBC[c]	Cover, Carbon Adsorber
Total Annualized Costs, $/Yr	1,230	1,040	1,840	2,500	3,590
Emission reduction, Mg/yr	1.84	2.86	3.19	3.19	3.89
Recovered solvent credit,[g] $/yr	820	1,260	1,400	1,400	1,710
Net annual control cost, $/yr	415	-220	430	1,090	1,880
Cost Effectiveness, $/Mg	230	75	140	340	480

[a] Freeboard Ratio.

[b] Refrigerated freeboard chiller.

[c] Also requires 0.75 freeboard ratio.

[d] Total installed capital cost annualized over 15 years at a 10 percent interest rate.

[e] Four percent of total installed capital cost.

[f] Three percent of total installed capital cost.

[g] Based on solvent price of $0.44 per kilogram.

TABLE 4-6. RETROFIT CONTROL COSTS FOR CONVEYORIZED DEGREASERS

	RFC[a]	Carbon Adsorber	Adsorber Drying Tunnel
Capital Costs, $			
Refrig. Freeboard	14,994	0	0
Carbon Adsorber	0	58,310	58,310
Auxiliary	0	0	11,900
Installation Costs, $			
Refrig. Freeboard	407	0	0
Carbon Adsorber	0	11,900	11,900
Auxiliary Equipment	0	0	2,380
Additional Plant Space	175	4,998	5,998
Total Capital Costs, $	15,576	75,208	90,488
Operating Costs, $/Yr			
Capital Charges[b]	2,047	9,882	11,890
Adm., Ins., & Taxes[c]	623	3,008	3,620
Operating Labor	0	0	0
Maintenance[d]	467	2,256	2,715
Utilities			
Electricity	195	277	277
Steam	-	626	626
Cooling Water	-	62	62
Total Annualized Cost, $/Yr	3,330	16,110	19,190
Emission Reduction, Mg/Yr	9.84	10.9	12.4
Recovered Solvent Credit, $/Yr[e]	4,330	4,795	5,455
Net Annualized Costs, $/Yr	-1,000	11,315	7,875
Cost of Control, $/Mg	-100	1,040	640

[a] Refrigerated freeboard chiller.

[b] Total installed capital cost annualized over 15 years at a 10 percent interest rate.

[c] Four percent of total installed capital cost.

[d] Three percent of total installed capital cost.

[e] Based on solvent price of $0.44 per kilogram.

For open top vapor degreaser (OTVD) control cost development the degreaser size was assumed to be 1.5 m^2 and the operating schedule was assumed to be 1,500 hours (6 hr/day, 5 day/week, 50 week/yr). The uncontrolled emissions were based on an OTVD with a freeboard ratio of 0.5 and were estimated to be 8,770 kg/yr. This estimate assumes an 8-hour working day during which the degreaser is uncovered for six of these hours; the degreaser is idle for the remaining two hours. Five control options for OTVDs were investigated, including covers and raised freeboards, automated covers and raised freeboards, above-freezing refrigerated chillers, below freezing refrigerated chillers, and carbon adsorption systems. The controlled emissions are presented in Table 4-5, and are based on the following: (1) utilization of a cover with a control efficiency of 90 percent during idle time; (2) reduction of 15 percent in vaporization losses by increasing the freeboard ratio from 0.5 to 0.75; (3) reduction of 40 percent in vaporization losses by use of either above- or below-freezing chillers; (4) reduction of 40 percent in vaporization losses due to the use of an automated cover; (5) reduction of 65 percent in vaporization losses due to the use of a carbon adsorber; and (6) a 10 percent reduction in carry out losses due to use of a refrigerated freeboard device. Overall achievable emission reductions with these techniques were estimated to range from 21 percent to 44 percent.[9,12,13]

Conveyorized degreaser control cost estimates were based on a degreaser 3.0 m^2 in size with an operating schedule of 2,000 hours (8 hr/day, 5day/wk, 50 wk/yr). Uncontrolled emissions for a typical conveyorized degreaser were estimated to be 21,840 kg/yr. Three control options were examined for costing purposes, including refrigerated freeboard chillers, carbon adsorbers, and carbon adsorbers along with a drying tunnel. Controlled emissions are presented in Table 4-6 and are based on the following: (1) a 45 percent reduction in solvent loss due to the use of refrigerated freeboard chillers; (2) a 50 percent reduction in solvent loss due to the use of a carbon adsorber; and (3) a 15 percent reduction in carry-out emissions only, due to the use of a drying tunnel. Achievable emission reductions using these techniques are estimated to range from 45 percent to 57 percent.[9,12,13]

Estimates of the national emission reduction associated with controlling TCE emissions from degreasers were made using: (1) emission factors developed for uncontrolled cold cleaners, open top vapor degreasers, and conveyorized vapor degreasers; and (2) the estimated total number of uncontrolled degreasers in TCE service in 1983. It is estimated that about 26,170 Mg/yr TCE emissions can be reduced by the application of control techniques on uncontrolled cold cleaners, open top vapor degreasers, and conveyorized vapor degreasers. This represents a 50 percent reduction in TCE emissions from degreasers. Potential TCE emission reductions for each type of degreasers are 370 Mg/yr (cold cleaners), 10,900 Mg/yr (open top vapor degreasers), and 14,900 Mg/yr (conveyorized vapor degreasers). The details of the calculations for estimating national emission reduction are presented in Appendix A.

4.6 REGULATORY REQUIREMENTS

EPA has approved RACT guidelines for solvent degreasing operations that have been adopted by 32 States and the District of Columbia. The 10 States that have the highest estimated emissions of TCE from solvent degreasing, California, Ohio, New York, Michigan, Illinois, Pennsylvania, Indiana, Texas, Massachusetts, and New Jersey, have all adopted EPA-approved RACT. These 10 States account for about 59 percent of total degreasing emissions of TCE. In addition, EPA has proposed (but not promulgated) an NSPS that would control emissions from new solvent degreasers.

4.7 REFERENCES

1. Bollinger, J. C.. and J. L. Shumaker. Control of Volatile Organic Emissions from Solvent Metal Cleaning. U.S. Environmental Protection Agency. Research Triangle Park, N.C. Publication No. EPA-450/2-77-022. November 1977. 203 p.

2. Letter from Morgan, D. L., Cleary, Gottlieb, Steen, and Hamilton, to Rosensteel, R.E., EPA. February 22, 1985. HSIA data on trichloroethylene production and consumption.

3. Tankg, J. L. Industrial Survey of Halogenated Solvent Producers and Degreaser Manufacturers. GCA/Technology Division, Chapel Hill, North Carolina. July 1981.

4. Hoogheem, T. J., D. A. Horn, T. W. Hughes, and P. J. Marn (Monsanto Research Corporation). Source Assessment: Solvent Evaporation - Degreasing Operations. Prepared for U.S. Environmental Protection Agency. Cincinnati, OH. Publication No. EPA-600/2-79-019f. August 1979. 133 p.

5. Telecon. Pandullo, R. F., Radian Corporation, with Pokorny, J., Baron-Blakeslee, Inc. March 19, 1985. General information on solvent recycling.

6. Bureau of the Census. County Business Patterns 1982. U.S. Department of Commerce. Washington, D.C. Publication No. CBP-82. October 1984.

7. GCA Corporation. Organic Solvent Cleaners - Background Information for Proposed Standards. Prepared for U.S. Environmental Protection Agency. Research Triangle Park, N.C. Publication No. EPA-450/2-78-045a. October 1979. 282 p.

8. Memo from O'Brian, T., GCA, to D. A. Beck, EPA/CPB. March 2, 1982. Estimation of Solvent-Specific Control Costs.

9. Memo from Smith, M., GCA, to D. A. Beck, EPA/CPB. August 20, 1981. Background Information on Cost Analysis for Emission Guideline Document for Organic Solvent Cleaners.

10. Chemical Engineering plant cost index. Chemical Engineering, Volume 88, Number 8.

11. Chemical Engineering plant cost index. Chemical Engineering, Volume 92, Number 6.

12. Westlin, P. R., and J. W. Brown, Test Report - Solvent Drainage and Evaporation from Cold Cleaner Usage. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina. January 1978.

13. Suprenant, K. S. and D. W. Richards. Study to Support New Source Performance Standards for Solvent Metal Cleaning Operations. Prepared by the Dow Chemical Company for the U.S. Environmental Protection Agency. Contract No. 68-02-1329. April 1976.

5.0 DISTRIBUTION FACILITIES

Virtually all trichloroethylene produced is sold through chemical distributors. There are an estimated 300 chemical distributors handling chlorinated solvents. Table 5-1 presents the five largest TCE distributors handling about 93 percent of the total TCE sold through distributors. In general, distributors maintain as few as three to as many as 65 regional distribution facilities spread out across the nation. One chemical distributor estimated the number of regional distribution facilities at 500 nationwide.[1] Each regional distributor receives chemicals directly from the producer by tank truck or railcar. Transportation is provided by the distributor. The received chemicals are stored by regional distributors in 8,000 to 20,000 gallon fixed-roof storage tanks. The storage tanks used by regional distributors include vertical, horizontal, and underground tanks. Turnover times for storage tanks typically range from 2 weeks to a little over a month. Although the exact number of distributors and distribution facilities that handle TCE is not known, it is estimated that there are 96 TCE storage tanks owned by distributors, the majority of which are fixed-roof tanks. The procedure used to estimate the number of tanks is given in Appendix E.

5.1 EMISSIONS FROM DISTRIBUTION FACILITIES

Emissions from distribution facilities can be categorized as two types, storage and handling. Storage emissions include breathing and working losses from tanks. Handling emissions result from vapor displacement when drums and tank trucks are filled.

Storage and handling emissions of TCE from distribution facilities were estimated using AP-42 emission factors[7] and data supplied by the major distributors. The details of those calculations are presented in Appendix D. It is estimated that approximately 39 Mg of TCE were emitted in 1983 from distribution facilities. Storage emissions accounted for 21 Mg, while handling emissions were about 18 Mg.

TABLE 5-1. SUMMARY OF MAJOR TRICHLOROETHYLENE DISTRIBUTORS

Company	Number Of Distribution Facilities	Number Of TCE Storage Tanks	Typical Size (Gal)	Typical Size Turnover
Ashland[2]	61	52	8,000	3 wks - 1 mo
McKesson[3]	63	6	10,000	N/A
Chem-Central[4]	31	15	10,000	1 mo
Detrex[5]	25	10	15,000	1½ wks - 1 mo
Thompson-Hayward[6]	26	6	10,000	2 - 3 months

5.2 REGULATORY REQUIREMENTS

There are State and Federal regulations that may affect trichloroethylene distribution facilities. Most States have regulations for storage and handling of volatile organic liquids and a new source performance standard (NSPS) for storage of volatile organic liquids was proposed in October 1984. However, TCE may be exempted from these regulations due to its low vapor pressure. Generally, these regulations exempt organic liquids with a vapor pressure below 1.5 psia. The vapor pressure for TCE is 1.2 psia at 70°F and 1.5 psia at 80°F.

5.3 REFERENCES

1. Memo from Howle, R. H., Radian Corporation. March 4, 1985. Distribution of trichloroethylene, perchloroethylene, methylene chloride, and carbon tetrachloride.

2. Telecon. Sterett, R., Ashland Chemical Company, with Howle, R. H., Radian Corporation. February 7, 1985. Conversation on storage of chlorinated solvents.

3. Telecon. Eisner, D., McKesson Chemical Company, with Howle, R. H., Radian Corporation. February 7, 1985. Conversation on storage of chlorinated solvents.

4. Telecon. Trice, L., Chem-Central, with Howle, R. H., Radian Corporation. February 8, 1985. Conversation on storage of chlorinated solvents.

5. Telecon. Blumquist, R., Detrex, with R. H. Howle, Radian Corporation. February 9, 1985. Conversation on storage of chlorinated solvents.

6. Telecon. Hart, W., Thompson-Hayward, with R. H. Howle, Radian Corporation. February 18, 1985. Conversation on storage of chlorinated solvents.

7. U.S. Environmental Protection Agency. Compilation of Air Pollutant Emission Factors. Supplement 7. Research Triangle Park, North Carolina. Publication No. AP-42. August 1977.

6.0 MISCELLANEOUS SOURCES

About 10,000 Mg of trichloroethylene (TCE) were consumed in miscellaneous applications in 1983. These miscellaneous applications include use (1) as a solvent in adhesive formulations; (2) as a solvent in paints and coatings; (3) as a reaction chain transfer agent in polyvinyl chloride (PVC) production; and (4) in miscellaneous chemical synthesis and solvent applications.[1,2]

The estimated consumption and emissions of TCE emissions for each miscellaneous source category are presented in Table 6-1. It is estimated that air emissions in 1983 were about 3,430 Mg. The bulk of adhesives, paints, and coatings are used in household applications, although they are also used by industry. Trichloroethylene emissions from adhesives, paints, and coatings occur through evaporation upon application. Consequently, it is estimated that all the TCE consumed in these applications in 1983 was emitted. It is also estimated, for the purposes of this study, that all TCE consumed in the various chemical synthesis and solvent applications in 1983 was emitted.

Trichloroethylene is used in PVC production as a reaction chain transfer agent to create low molecular weight polymers. The PVC suspension process is the only process that uses TCE in this manner. TCE is used by about 15 percent of the companies using the suspension process.[3] Most of the TCE is destroyed in the chain transfer reaction. A recent EPA report estimates that about 6500 Mg were used as a reaction inhibitor in PVC production in 1978 and about 130 Mg were emitted.[4] It is assumed in Table 6-1 that the consumption and emissions of TCE in PVC production were the same in 1983 as they were in 1978. It should be noted that it was not within the scope of this study to identify all PVC producers using TCE. However, one facility was identified as using TCE as a reaction inhibitor in PVC production. As discussed in Chapter 3.0, Borden Chemical in Illiopolis, Illinois emitted about 1 Mg of TCE in 1983 during PVC production. The estimated TCE emissions from PVC production listed in Table 6-1 include the emissions from this Borden facility.

TABLE 6-1. 1983 TRICHLOROETHYLENE CONSUMPTION AND EMISSIONS FROM MISCELLANEOUS SOURCE CATEGORIES

Category	Consumption (Mg/Yr)	Emissions (Mg/Yr)
Adhesive Formulations	420	420
Paints and Coatings	520	520
PVC Production	6,500	130
Miscellaneous (Chemical Synthesis and General Solvent)	2,340	2,340
TOTAL	9,780	3,430

6.1 REFERENCES

1. Letter from Morgan, D.L., Cleary, Gottlieb, Steen and Hamilton to R. E. Rosensteel, EPA:ESED. February 22, 1985. Halogenated Solvents Industry Alliance (HSIA) information on trichloroethylene consumption.

2. Chemical Products Synopsis - Trichloroethylene. Cortland, New York, Mannsville Chemical Products. March 1984.

3. Telecon. Barr, J., Air Products Co., with Murphy, P. B., Radian Corporation, July 18, 1985. Information on TCE useage in PVC manufacturing.

4. Memo from Callahan, M.A., TSPC Solvents Work Group #2 to M.C. Bracken, Toxic Substances Priorities Committee. February 1, 1982. Final report of TSPC Solvents Work Group #2.

7.0 PUBLICLY OWNED TREATMENT WORKS (POTWs)

7.1 EMISSION ESTIMATES

A recent EPA study described a methodology for estimating trichloroethylene (TCE) emissions from publicly owned treatment works (POTWs).[1] TCE emissions are believed to occur through volatilization during treatment of industrial discharges containing TCE. According to the EPA study, emission estimates were based on data from the 1,600 POTWs nationwide identifed as treating industrial discharges. Data obtained include percent of total inflow to POTW attributable to industrial discharges, types of industries discharging to POTW, and type of treatment at the POTW. A specific emission factor for TCE was developed from the results of a prior EPA study providing mass-balance information on several pollutants for 50 POTWs. Emissions for an individual POTW were estimated using the emission factor and the assumed amount of TCE in the waste stream entering the POTW. Using this methodology and aggregating results for individual POTWs it is estimated that about 1,400 Mg of TCE are emitted annually in the U.S. from POTWs.[1,2]

This national emission estimate is at best rough. The TCE emission factor used is based on a sample of 50 POTWs. These 50 were not selected to be a statistically valid representation of all POTWs in the country. In fact, they more accurately represent large POTWs with a relatively high proportion of industrial discharge in the influent.[2]

7.2 REFERENCES

1. Memorandum and attachments from Lahre, T., EPA:AMTB, to Southerland, J. H., EPA:AMTB. December 5, 1983. Initial look at available emissions data on POTWs.

2. U.S. Environmental Protection Agency. Hazardous Air Pollutants - Air Exposure and Preliminary Risk Appraisal for 35 U.S. Counties. Office of Policy Analysis, Washington, D.C. September 1984.

APPENDIX A

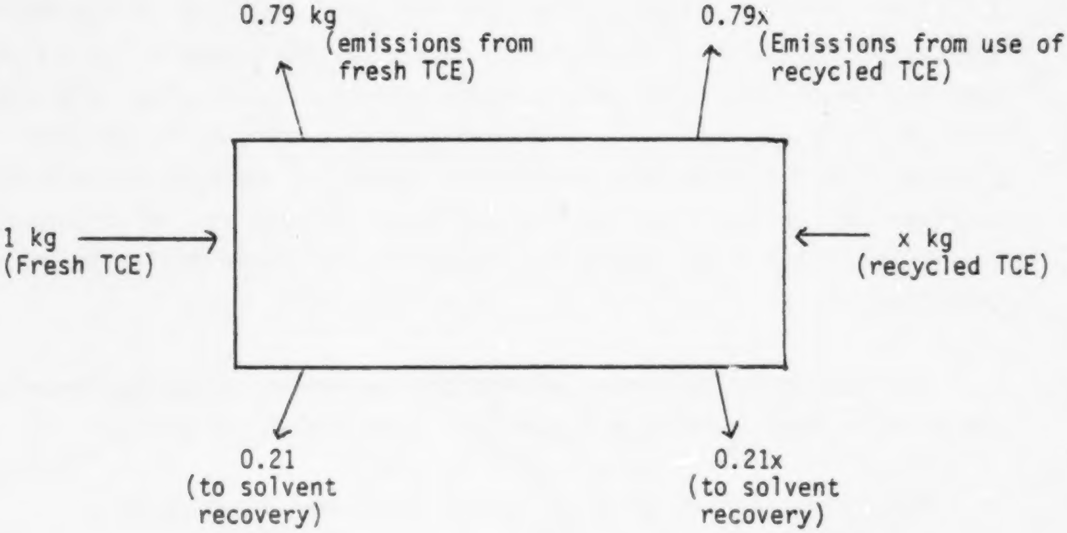
MATERIAL BALANCE FOR TCE EMISSIONS FROM DEGREASING OPERATIONS

A.1 MATERIAL BALANCE

(1)
- Fraction of degreasing use of TCE in cold cleaning = 0.05
  Fraction of degreasing use of TCE in vapor degreasing = 0.95
- Emission factors:
  - cold cleaning: 0.43 kg/kg used
  - open top degreasing: 0.78 kg/kg used
  - conveyorized degreasing: 0.85 kg/kg used
- Assuming TCE usage in vapor degreasing is divided equally between open top and conveyorized vapor degreasing, a weighted average emission factor is calculated as follows:

$$(0.05)(0.43) + (0.475)(0.78) + (0.475)(0.85) = 0.79 \text{ kg/kg used}$$

(2)
- For every kg of fresh TCE used, 0.79 kg is emitted. Assume all of the remaining 0.21 kg is sent to solvent recovery.
- Estimate that 75 percent of all solvent sent to recovery is recycled.
- Calculate emissions as follows:


0.79 kg
(emissions from fresh TCE)
0.79x
(Emissions from use of recycled TCE)
1 kg
(Fresh TCE)
x kg
(recycled TCE)
0.21
(to solvent recovery)
0.21x
(to solvent recovery)

$x = 0.75\ (0.21 + 0.21x)$

$x = 0.19$ (Amount of recycled TCE used per kg of fresh TCE used)

$0.72x = 0.15$ (Amount of recycled TCE emitted per kg of fresh TCE used)

Total TCE emitted per kg of fresh TCE used = 0.79 + 0.15

= 0.94 kg

A.2 NATIONAL EMISSION REDUCTION CALCULATIONS

National emission reduction can be calculated by estimating the amount of solvent emitted by the degreasers that are presently uncontrolled and applying a control efficiency to these emissions. The emission factors presented in Section A.1 for cold cleaners, open top vapor degreasers, and conveyorized vapor degreasers are overall emission factors representing the average emission factor from controlled and uncontrolled degreasers. An uncontrolled degreaser emission factor was developed for the three types of degreasers so that the national emissions from uncontrolled degreasers could be calculated. An uncontrolled degreaser is considered to be one that does not have the most stringent control technique for its degreaser type. These control techniques were described in Chapter 4. For example, the most stringent control technique for an open top vapor degreaser is a carbon adsorber. Therefore, an uncontrolled open top vapor degreaser is one that does not control emissions with a carbon adsorber. In reality, degreasers have levels of controls ranging from no control techniques to the most stringent control techniques available. Therefore, defining an uncontrolled degreaser as one that does not have the most stringent control techniques for its degreaser type results in an overestimate of the achievable emission reduction.

Information on the number of uncontrolled versus controlled degreasers was obtained from industry contacts.[1,2] These are as follows:

- Ratio of uncontrolled/controlled cold cleaners = 0.65/0.35

- Ratio of uncontrolled/controlled open top vapor degreasers = 0.99/0.01
- Ratio of uncontrolled/controlled conveyorized vapor degreasers = 0.95/0.05

The uncontrolled degreaser emission factors were then calculated according to the following equation:

(1) $y = (a)x + (b)(c)\,x$

where:

y = overall degreaser emission factor, kg/kg solvent consumed
a = fraction of uncontrolled degreasers
x = uncontrolled degreaser emission factor, kg/kg solvent consumed
b = fraction of controlled degreasers
c = 1 - achievable emission reduction

Since emission reduction is calculated only for presently uncontrolled degreasers, the total solvent consumption must be adjusted to include only the solvent used in uncontrolled degreasers. The adjusted solvent consumption levels were calculated according to the equation:

(2) $z = (s)(t)(u)$

where:

z = total solvent consumed by uncontrolled degreasers by degreaser type, Mg/yr
s = total solvent consumption by all degreasers (fresh solvent plus recycled solvent = total emissions divided by emission factor for fresh TCE), Mg/yr
t = fraction of consumption by degreaser type
u = fraction of uncontrolled degreasers by degreaser type

The uncontrolled emission factors were applied to the total amount consumed by uncontrolled sources within each degreaser type to yield the national uncontrolled emissions for the degreaser type. Applying the control efficiency to the national uncontrolled emissions gives the emission reduction for the degreaser type. These calculations proceed according to the equation:

(3) $r = (z)(x)(v)$

where:

r = emission reduction for degreaser type, Mg/yr

z = total solvent consumed by uncontrolled degreasers by degreaser type, Mg/yr

x = uncontrolled degreaser emission factor (kg/kg solvent consumed)

v = achievable emission reduction

Calculations:

I. Cold Cleaners

(1)
$$\begin{aligned} y &= (a)x + (b)(c)x \\ 0.43 &= (0.65)x + (0.35)(1-0.35)x \\ x &= 0.49 \end{aligned}$$

(2)
$$\begin{aligned} z &= (s)(t)(u) \\ z &= \left(\frac{52{,}600}{0.79}\right)(0.05)(0.65) \\ z &= 2{,}160 \text{ Mg/yr} \end{aligned}$$

(3)
$$\begin{aligned} r &= (z)(x)(v) \\ r &= 2{,}160(0.49)(0.35) \\ r &= 370 \text{ Mg/yr} \end{aligned}$$

II. Open Top Vapor Degreasers

(1)
$$\begin{aligned} y &= (a)x + (b)(c)x \\ 0.78 &= (0.99)x + (0.01)(1-0.44)x \\ x &= 0.78 \end{aligned}$$

(2)
$$\begin{aligned} z &= (s)(t)(u) \\ z &= \left(\frac{52{,}600}{0.79}\right)(0.475)(0.99) \\ z &= 31{,}600 \text{ Mg/yr} \end{aligned}$$

(3) $r = (z)(x)(v)$

$r = (31{,}600)(0.78)(0.44)$

$r = 10{,}900$ Mg/yr

III. Conveyorized Vapor Degreasers

(1) $y = (a)x + (b)(c)x$

$0.85 = (0.95)x + (0.05)(1-0.57)x$

$x = 0.87$

(2) $z = (s)(t)(u)$

$z = (\frac{52{,}600}{0.79})(0.475)(0.95)$

$z = 30{,}000$ Mg/yr

(3) $r = (z)(x)(v)$

$r = (30{,}000)(0.87)(0.57)$

$r = 14{,}900$ Mg/yr

A.3 REFERENCES

1. Telecon. Murphy, P. B., Radian Corporation, with Pokorny, J., Baron-Blakeslee, Inc. August 9, 1985. Information on degreasing control technology.

2. Telecon. Murphy, P. B., Radian Corporation, with Barr, F., Graymills, Corporation. August 9, 1985. Information on degreasing control technology.

APPENDIX B

METHODS USED FOR ESTIMATING STORAGE TANKS AND EQUIPMENT LEAK EMISSIONS

B.1 EMISSION FACTORS FOR FIXED-ROOF STORAGE TANKS

B.1.1 Emission Equations

The major types of emissions from fixed-roof storage tanks are breathing and working losses. Emission equations for breathing and working losses from storage tanks were developed in EPA Publication No. AP-42. The equations used in estimating emissions rates for fixed-roof tanks storing VOL are:

- $L_T = L_B + L_W$
- $L_B = 1.02 \times 10^{-5} M_v \left(\frac{P}{14.7-P}\right)^{0.68} D^{1.73} H^{0.51} T^{0.5} F_p C K_c$
- $L_W = 1.09 \times 10^{-8} M_v P V N K_n K_c$

where, L_T = total loss (Mg/yr)

L_B = breathing loss (Mg/yr)

L_W = working loss (Mg/yr)

B.1.2 Parameter Values and Assumptions

The following C_2HCl_3 physical property values, plant-specific information, and engineering assumptions were used to estimate the emission losses:

M_v = molecular weight of product vapor (lb/lb mole);
for C_2HCl_3, M_v = 131.5

P = true vapor pressure of product, function of temperature.

D = tank diameter (ft); dependent upon plant-specific information.

C = tank diameter factor (dimensionless):
for diameter $\geq$ 30 feet, C = 1
for diameter < 30 feet, $C = 0.0771 D - 0.0013(D)^2 - 0.1334$

V = tank capacity (gal); dependent upon plant-specific information

N = number of turnovers per year (dimensionless); dependent upon plant-specific information

T = average diurnal temperature change in °F; plant specific information

F_p = paint factor (dimensionless); the storage tanks were assumed to be in good condition and painted white; therefore, $F_p = 1$ (see Table B-1)

H = average vapor space height (ft): used tank-specific values or an assumed value of one-half the tank height (H/2)

K_C = product factor (dimensionless) = 1.0 for VOL

K_n = turnover factor (dimensionless); dependent upon plant-specific information

for turnovers > 36, $K_n = \frac{180 + N}{6N}$

for turnovers $\leq$ 36, $K_n = 1$

B.1.3 Sample Calculation

The following sample calculation is provided to demonstrate the evaluation of emissions from a typical fixed-roof storage tank containing C_2HCl_3. For the general equations,

$$L_T = L_W + L_B$$

$$L_B = 1.02 \times 10^{-5} M_V \left(\frac{P}{14.7-P}\right)^{0.68} D^{1.73} H^{0.51} T^{0.5} F_p C K_C$$

$$L_W = 1.09 \times 10^{-8} M_V P V N K_n K_C$$

where,
$M_V = 131.5$
$P = 1.50$ psia (@ 80°F)
$D = 37$ ft
$C = 1$
$V = 233{,}000$ gallons
$N = 10$
$T = 20$°F
$F_p = 1.0$
$H = 14$ ft
$K_C = 1.0$
$K_n = 1$

TABLE B-1. PAINT FACTORS FOR FIXED-ROOF TANKS[1]

Tank Color		Paint factors (F_p) Paint condition	
Roof	Shell	Good	Poor
White	White	1.00	1.15
Aluminum (specular)	White	1.04	1.18
White	Aluminum (specular)	1.16	1.24
Aluminum (specular)	Aluminum (specular)	1.20	1.29
White	Aluminum (diffuse)	1.30	1.38
Aluminum (diffuse)	Aluminum (diffuse)	1.39	1.46
White	Gray	1.30	1.38
Light gray	Light gray	1.33	1.44
Medium gray	Medium gray	1.40	1.58

the emissions from this storage tank are:

$$L_B = 1.02 \times 10^{-5} (131.5)\left(\frac{1.5}{14.7-1.5}\right)^{0.68} (37)^{1.73}(14)^{0.51}(20)^{0.5}(1)(1)(1)$$

$$= 2.71 \text{ Mg/yr}$$

$$L_w = 1.09 \times 10^{-8} (131.5)(1.5)(233{,}000)(10)(1)(1)$$

$$= 5.01 \text{ Mg/yr}$$

$$L_T = 2.71 \text{ Mg/yr} + 5.01 \text{ Mg/yr} = 7.72 \text{ Mg/yr}$$

B.2 EMISSION FACTORS FOR INTERNAL FLOATING ROOF STORAGE TANKS

B.2.1 Emission Equations

Emissions from internal floating roof tanks can be estimated from the following equations:[1] (Note that these equations apply only to freely vented internal floating roof tanks.)

$$L_T = L_w + L_r + L_f + L_d$$

where, L_T = the total loss (Mg/yr)

L_w = the working loss (Mg/yr) = $\frac{(0.943)\ Q\ C\ W_L}{D} \left[1 + \frac{N_c F_c}{D}\right] /2205$

where, D = tank diameter (ft)

N_c = number of columns (dimensionless); (see Table B-2)

F_c = effective column diameter (ft); 1.0 assumed

L_r = the rim seal loss (Mg/yr) = $(K_r D)\ P^*\ M_v\ K_C/2205$

L_f = the fitting loss (Mg/yr) = $(F_f)\ P^*\ M_v\ K_C/2205$

L_d = the deck seam loss (Mg/yr) = $(F_d\ K_d\ D^2)\ P^*\ M_v\ K_C/2205$

B.2.2 Parameter Values and Assumptions

The assumptions and values used to calculate emissions from internal floating roof tanks are:

Q = product average throughput (bbl/yr); tank capacity (bbl/turnover) x turnovers/yr; dependent upon plant-specific information

C = product withdrawal shell clingage factor ($bbl/10^3\ ft^2$); use $0.0015\ bbl/10^3 ft^2$ for VOL in a welded steel tank with light rust (0.0075 for dense rust)

W_L = density of product (lb/gal); for C_2HCl_3, 12.3 lb/gal

D = tank diameter (ft)

N_C = number of columns (dimensionless); (see Table B-2)

F_C = effective column diameter (ft); 1.0 assumed

D = the tank diameter (ft); dependent upon plant-specific information

M_V = the average molecular weight of the product vapor (lb/lb mole). For C_2HCl_3, $M_V = 131.5$

K_C = the product factor (dimensionless) = 1.0 for VOL

2205 = constant (lb/Mg)

P^* = the vapor pressure function (dimensionless)

$P^* = 0.068\ P/((1 + (1 - 0.068\ P)^{0.5})^2)$

P = the true vapor pressure of the material stored (1.5 psia for C_2HCl_3)

= the rim seal loss factor (lb mole/ft yr) that for an average fitting seal is as follows:

Seal system description	K_r (lb mole/ft yr)
Vapor-mounted primary seal only	6.7
Liquid-mounted primary seal only	3.0
Vapor-mounted primary seal plus secondary seal	2.5
Liquid-mounted primary seal plus secondary seal	1.6

F_f = the total deck fitting loss factor (lb mole/yr)

$$= \sum_{i=1}^{n} (N_{f_i} K_{f_i}) = [(N_{f_1} K_{f_1}) + (N_{f_2} K_{f_2}) + \ldots + (N_{f_n} K_{f_n})]$$

where, N_{f_i} = number of fittings of a particular type (dimensionless). N_{f_i} is determined for the specific tank or estimated from Tables B-2 and B-3. The values used for these emissions estimates are designated by * in Table B-3.

K_{f_i} = deck fitting loss factor for a particular type fitting (lb mole/yr). K_{f_i} is determined for each fitting type from Table B-3. The values used for these emissions estimates are designated by *.

n = number of different types of fittings (dimensionless)

F_d = the deck seam length factor (ft/ft^2)

= 0.15, for a deck constructed from continuous metal sheets with a 7 ft spacing between seams

= 0.33, for a deck constructed from rectangular panels 5 ft by 7.5 ft

= 0.20, an approximate value for use when no construction details are known

K_d = the deck seam loss factor (lb mole/ft yr)

= 0.34 for nonwelded roofs

= 0 for welded decks

B.2.3 Sample Calculation

The following sample calculation is provided to demonstrate the evaluation of emissions from a typical storage tank with an internal floating roof containing C_2HCl_3. For the general equations,

$$L_T = L_W + L_r + L_f + L_d$$

$$L_W = \frac{(0.943)QCW_L}{D}\left[1 + \frac{N_C F_C}{D}\right]/2205$$

$$L_r = (K_r D)\ P^*\ M_V\ K_C/2205$$

TABLE B-2. TYPICAL NUMBER OF COLUMNS AS A FUNCTION OF TANK DIAMETERS

Tank Diameter Range D (Ft) Greater Than	And	Less Than Or Equal To	Typical Number Columns, N_c
0		85	1
85		100	6
100		120	7
120		135	8
135		150	9
150		170	16
170		190	19
190		220	22
220		235	31
235		270	37
270		275	43
275		290	49
290		330	61
330		360	71
360		400	81

TABLE B-3. SUMMARY OF DECK FITTING LOSS FACTORS (K_f) AND TYPICAL NUMBER OF FITTINGS (N_f)

Deck Fitting Type	Deck Fitting Loss Factor, K_f (lb mole/yr)	Typical Number Of Fittings (N_f)
1. Access Hatch		
A. Bolted cover, gasketed	1.6	1
B. Unbolted cover, gasketed	11 *	
C. Unbolted cover, ungasketed	25	
2. Automatic Gauge Float Well		
A. Bolted cover, gasketed	5.1	1
B. Unbolted cover, gasketed	15 *	
C. Unbolted cover, ungasketed	28	
3. Column Well		(see Table B-2)
A. Built-up column-sliding cover, gasketed	33	
B. Built-up column-sliding cover, ungasketed	47	
C. Pipe column-flexible fabric sleeve seal	10	
D. Pipe column-sliding fabric gasketed	19 *	
E. Pipe column-sliding cover, ungasketed	32	
4. Ladder Well		1
A. Sliding cover, gasketed	56 *	
B. Sliding cover, ungasketed	76	
5. Roof Leg or Hanger Well		
A. Adjustable	7.9 *	$(5 + \frac{D}{10} + \frac{D^2}{600})^{a,\ b}$
B. Fixed	0	
6. Sample Pipe or Well		1
A. Slotted pipe-sliding cover, gasketed	44 *	
B. Slotted pipe-sliding cover, ungasketed	57	
C. Sample well-slit fabric seal, 10% open area	12	
7. Stub Drain, 1-inch diameter	1.2 *	$(\frac{D^2}{125})$ b
8. Vacuum Breaker		1
A. Weighted mechanical actuation, gasketed	0.7 *	
B. Weighted mechanical actuation, ungasketed	0.9	

[a] Not used on welded, contact internal floating decks.

[b] D= tank diameter (ft).

$L_f = (F_f)\ P^*\ M_v\ K_c/2205$

$L_D = (F_d K_d D^2)\ P^*\ M_v\ K_c/2205$

where, M_v = 131.5 lb/lb mole

P^* = 0.0268

Q = 500,000 bbl/yr

C = 0.0015

W_L = 12.3 lb/gal

D = 30 ft

N_c = 1

F_c = 1.0

K_r = 6.7 lb mole/ft yr

K_c = 1.0

F_f = 242 lb mole yr

F_d = 0.20

K_d = 0

the emissions from this storage tank are:

$$L_W = \frac{(0.943)(500,000)(0.0015)(12.3)}{30} \quad \left(1 + \frac{(1)(1)}{30}\right) /2205$$

$$= 0.136 \text{ Mg/yr}$$

$$L_r = ((6.7)(30))(0.0268)(131.5)(1.0)/2205$$

$$= 0.321 \text{ Mg/yr}$$

$$L_f = (242)(0.0268)(131.5)(1.0)/2205$$

$$= 0.387 \text{ Mg/yr}$$

$$L_D = ((0.20)(0.34)(30)^2)(0.0268)(131.5)(1.0)/2205$$

$$= 0.0978 \text{ Mg/yr}$$

$$L_T = 0.136 \text{ Mg/yr} + 0.321 \text{ Mg/yr} + 0.387 \text{ Mg/yr} + 0.0978 \text{ Mg/yr}$$

$$L_T = 0.94 \text{ Mg/yr}$$

B.3 EQUIPMENT LEAK EMISSIONS - SAMPLE CALCULATIONS

Emissions were estimated from the number of equipment leak sources (provided by the plant), the percentage of C_2HCl_3 in the stream (provided by the plant), and the emission factors for each type of equipment (from the SOCMI AID).[2] The following sample calculations illustrate the procedure.

Emissions Source	Number		% C_2HCl_3 Service		Mg/yr source Emission Factor[a]		Total Emissions Mg/yr
Pump seals	3	x	7.5	x	0.043	=	0.097
	6	x	50.5	x	0.043	=	1.3
	2	x	87.5	x	0.043	=	0.75
	12	x	100.0	x	0.043	=	5.2

Emissions Source	Number		% C_2HCl_3 Service		Mg/yr source Emission Factor[a]		Total Emissions Mg/yr
Compressors	1	x	87.5	x	2.0	=	1.8
Flanges	4	x	5.0	x	0.01	=	0.002
	112	x	7.5	x	0.01	=	0.084
	30	x	18.0	x	0.01	=	0.054
	235	x	50.5	x	0.01	=	1.2
	66	x	87.5	x	0.01	=	0.58
	456	x	100.0	x	0.01	=	4.56
Valves (gas)	4	x	5.0	x	0.05	=	0.01
	8	x	7.5	x	0.05	=	0.030
	3	x	50.5	x	0.05	=	0.976
	4	x	87.5	x	0.05	=	0.18
	11	x	100.0	x	0.05	=	0.55
Pressure Relief Devices (gas)	2	x	5.0	x	0.91	=	0.091
	4	x	50.5	x	0.91	=	1.8
	6	x	100.0	x	0.91	=	5.5
Sampling Connections	5	x	5.0	x	0.13	=	0.033
	3	x	50.5	x	0.13	=	0.20
	1	x	87.5	x	0.13	=	0.11
	3	x	100.0	x	0.13	=	0.39
Open Ended Lines	1	x	100.0	x	0.015	=	0.015
					TOTAL	=	24.6

Annual Emissions = 24.6 Mg/yr

---

[a] U. S. Environmental Protection Agency. Fugitive Emission Sources of Organic Compounds - Additional Information on Emissions, Emission Reductions, and Costs. Research Triangle Park, NC. Publication No. EPA-450/3-82-010. April 1982.

B.4 REFERENCES

1. U. S. Environmental Protection Agency. VOC Emissions from Volatile Organic Liquid Storage Tanks - Background Information for Proposed Standards. Research Triangle Park, North Carolina. Publication No. EPA-450/3-81-003a. July 1984. 252 pp.

2. U.S. Environmental Protection Agency. Fugitive Emission Sources of Organic Compounds - Additional Information on Emissions, Emission Reductions, and Costs. Research Triangle Park, N.C. Publication No. EPA-450/3-82-010. April 1982.

APPENDIX C

METHODS FOR ESTIMATING EMISSION CONTROL COSTS

C.1 PROCESS VENT EMISSIONS CONTROL COST ESTIMATION

The cost estimates for process vent emission control are based on the use of thermal incineration. The procedure for estimating these costs uses the methods presented in the Air Oxidation Processes Control Techniques Guidelines (CTG) document.[1] A detailed discussion of the incinerator costing methods may be found in Chapter 5 of this document. It should be noted that these incinerator costing procedures are designed for vent streams having high flowrates. Since the vent streams containing TCE generally have lower flowrates, the cost estimates for process vent emission control may be somewhat overstated. Further work will be performed to develop incinerator costing procedures for lower flowrate vent streams if regulatory development proceeds.

The total installed capital cost of control is determined using the following equation:

Total Installed Capital Cost (10^3\$) = (# of incinerators) x (escalation factor) x (C1 - (Waste Heat Boiler Correction Factor) + (C2 x (Flowrate per incinerator ÷ Design Vent Size Factor)^{C3}) + (pipe rack cost) + (additional ductwork cost)

where: C1, C2, and C3 are coefficients from Table C-1 that depend upon heating value and halogenation status of a given vent stream; waste heat boiler correction factor of 40 (10^3\$) is used for vent streams with flowrates below 700 scfm, where no heat recovery in a waste heat boiler is assumed; escalation factor of 0.90 escalates costs to 1978 dollars;

design vent size factor of 0.95 increases vent stream flowrate for costing purposes;

pipe rack cost is calculated using the equation presented in Table C-2;

additional ductwork cost is calculated using the equation presented in Table C-3.

TABLE C-1. TOTAL INSTALLED CAPITAL COST AS A FUNCTION OF VENT STREAM FLOW RATE

Category	Maximum Flowrate Per Unit (10^3 scm/min)	Minimum Net Heating Value (MJ/scm)	Maximum Net Heating Value (MJ/scm)	Fabricated Equipment Cost Escalation Factor	C1	C2	C3
A1[a]	0.74	0.0	3.5	0.90	803.11	12.83	0.88
A2[a]	0.74	3.5	-	0.90	786.61	12.44	0.88
B	1.42	0.0	0.48	0.90	259.88	4.91	0.88
C	1.42	0.48	1.9	0.90	297.99	2.84	0.88
D	1.25	1.9	3.6	0.90	236.35	3.23	0.88
E[a]	1.25	3.6	-	0.90	236.35	3.23	0.88

[a] Halogenated vent stream.

[b] Dilution flow rate is used in capital cost equation.
Dilution flow rate = (design flow rate) x (original heating value) ÷ (3.65 MJ/scm).

TABLE C-2. ADDITIONAL DUCT COST[1,2]

Additional duct cost (10^3 \$) = (length) x (cost per unit length) x (installation factor) x (duct escalation factor) ÷ 1000

Cost per unit length = 1.37L - 1.76

where L = duct diameter in inches

$$\text{Diameter} = \left[\frac{\text{Flow rate (ft}^3\text{/min)}}{\text{Linear velocity (ft/min)}} \times \frac{4}{\pi} \right]^{\frac{1}{2}}$$

$$= \left[\frac{\text{Flow rate (ft}^3\text{/min)}}{\text{2000 ft/min}} \times \frac{4}{3.1412} \right]^{0.5}$$

if linear velocity is assumed to be 2000 ft/min

Additional duct length = 150 ft + (additional vents x 100 ft/vent)

Installation factor = 1.087

Escalation factor (from 1977 to 1978) = 1.088

TABLE C-3. PIPE RACK COST[1,2]

Pipe rack cost ($10^3\ \$$) = (pipe rack length) x (cost per unit length) x (installation factor) x (pipe rack deescalation factor) ÷ 1000

Pipe rack length = 250 ft + (# additional vents x 100 ft/vent)

Cost per unit length = $32.045/ft

Installation factor = 1.087

Escalation factor (1982 to 1978) = 0.746

Table C-4. Operating Factors For Each Design Category

Category	Minimum Net Heating Value (MJ/scm)	Maximum Net Heating Value (MJ/scm)	Ratio of Flue Gas Flow to Offgas Flow[a]	Heat Recovery Factor (MJ/scm)	Pressure Drop (Inches H_2O)44.45	Operating Labor Cost ($1,000/YR)	Natural Gas Use Coefficients G0	G1	G2	G3
A1[b]	0	3.5	2.9	3.38	22[c]	23.50	0	4.56	-0.985	0
A2[b]	3.5	-	2.9	3.38	22[c]	23.50	0	0.329	0	0
B	0.	0.48	1.9	0	10[d]	20.88	0.425	0.666	-1.29	0.015
C	0.48	1.9	2.3	0	10[d]	20.88	0	2.39	-1.22	0
D	1.9	3.6	2.5	0	6[e]	11.75	0	0.183	0	0
E	3.6	-	2.5	0	6[e]	11.75	0	0.183	0	0

[a] Both at standard conditions.

[b] Offgas contains halogenated compounds.

[c] Includes 6 inches across the combustion chamber, 4 inches across the waste heat boiler, and 12 inches across the scrubber.

[d] Includes 6 inches across the combustion chamber and 4 inches across the recuperative heat exchanger.

[e] Across the combustion chamber.

TABLE C-5. ANNUALIZED COST FACTORS

All Factors are Based on June 1980

Direct

Operating Labor: $8.50/hr
Operating Labor Factor: 2400 Man-hr/yr (Categories A1-A2)
2133 Man-hr/yr (Categories B-C)
1200 Man-hr/yr (Categories D-E)

Supervisory Labor: $8.50/hr x (0.15)

Total Labor: [($8.50/hr x 1.15) + (0.03 of Total Installed Capital)]

Overhead Labor: 0.80 of Total Labor
Electricity: $0.0279/kWh
Natural Gas: $4.16/GJ
Heat Recovery Credit: $4.16/GJ
Quench Water Price: $0.22/Thousand Gallons
Scrubbing Water Price: $0.22/Thousand Gallons
Caustic Price: $0.0436/lb[a]
Maintenance Labor Plus Materials Factor = 0.06 of Total Installed Capital

Indirect ("Capital Charges")

Interest Rate = i = 10%

Incinerator Lifetime = 10 Years = N
Capital Recovery Factor = $\frac{i\,(1 + i)^N}{(1 + i)^N - 1}$

= 0.163 of Total Installed Capital

Taxes, Insurance and Administrative Charges Factor = 0.04 of Total Installed Capital

Overall Capital Charges Factor = 0.203 of Total Installed Capital

Overall Taxes and Maintenance Factor = 0.10 of Total Installed Capital

---

[a] Fifty percent liquid solution of caustic soda.

[b] Memo to Hurley, E., EEA, from Galloway, J., EEA. January 13, 1981. Average capacity utilization for the air oxidation industry.

A sample calculation for incinerator costing is shown in Table C-6. The calculation is based on vent stream parameters obtained from the Stauffer Chemical Company (Le Moyne, Alabama) Section 114 letter response. The cost estimate was initially calculated in 1978 dollars and then was updated to 1984 dollars using the annualized cost escalation factor shown in Table C-7.

C.2 COST CALCULATIONS FOR INSTALLING INTERNAL FLOATING ROOFS IN FIXED ROOF TANKS

The following equations were used to calculate the capital and annualized cost for the installation of a mild steel welded contact internal floating roof to a fixed roof storge tank. This internal floating roof utilizes both primary (constructed of Teflon^R) and secondary (constructed of Viton^R) seals.

C.2.1 Capital Cost (4th Quarter 1982 Dollars)

1. Degassing Cost[4]

Cost = \$130.8 $V^{0.5132}$ or \$1,000, whichever is greater where V = tank volume in cubic meters.

2. Estimated Installation Cost[4]

a. Basic cost of roof and primary seal:
Cost = (1.91 + 2.54 x D) x \$1,000 + (\$204 x D)
D = tank diameter in meters

(The \$204 x D cost reflects the additional cost of using Teflon^R coated fiberglass to protect against TCE attack versus the standard polyurethane coating.)[5]

TABLE C-6. SAMPLE CALCULATION FOR INCINERATOR COSTING

1. Capital Cost (10^3 \$)	= (# incinerators) x (incinerator capital cost per unit) x (escalation factor) = (# incinerators) x (803.11 - 40.0 + 12.83 x $(\text{flow}/0.95)^{0.88}$) x escalation factor = 1 x (803.11 - 40.0 + 12.83 $(14.2)^{0.88}$) x 0.9 = 806.1
2. Additional Duct Cost (10^3 \$)	= (length) x (cost per unit length) x (escalation factor) x (installation factor) = 350 ft. x $(((500\ \text{ft}^3/\text{min} \times 4 \div 2000 \div 3.1412))^{0.5}$ x 12 x 1.37 - 1.76) x 1.088 x 1.087 ÷ 1000 = 3.111
3. Pipe Rack Cost (10^3 \$)	= (length) x (cost per unit length) x (installation factor) x (pipe rack deescalation factor) x (retrofit correction factor) ÷ 1000 = 250 ft. + (# additional vents x 100 ft./vent) x \$32.045/ft. x 1.087 x 0.746 x ÷ 1000 = 11.693
4. Total Installed Total Capital	= Capital cost (10^3 \$) + extra duct cost (10^3 \$) + pipe rack cost (10^3 \$) = 806.1 + 3.111 + 11.693 = 820.9

(continued)

TABLE C-6. (Continued)

5. Natural Gas Use (MJ/yr) = (minutes per year) x (supplemental gas required per minute)
= 0.5256 10^6 min/yr x G_0 + flow x (G_1 + G_2 x H_T)
= 0.5256 10^6 min/yr x (3.96) x (4.53 - 0.985 x 1.49) MJ/min)
= 6.37 MJ/yr

6. Natural Gas Cost (10^3 \$) = Natural gas price (\$/10^9 J) x natural gas use (MJ/yr)
= \$4.16/GJ x 6.37 MJ
= 26.2

7. Operating Labor Cost (10^3 \$) = Wage (\$/hr) x labor factor (hr/yr) ÷ 1000
= \$8.50/hr x 2400 hrs
= 20.4

8. Supervisory Labor Cost (10^3 \$) = Operating labor cost (10^3/yr) x 0.15
= 20.4 (10^3 \$/yr) x 0.15
= 3.06

9. Maintenance Labor Cost (10^3 \$) = Installed capital cost (10^3 \$) x 0.03
= 820.9 (10^3) \$ x 0.03
= 24.63

10. Overhead Labor Cost (10^3 \$) = Operating labor cost (10^3 \$) + supervisory labor cost (10^3 \$) + maintenance labor cost (10^3 \$) x 0.80
= (20.40 + 3.06 + 24.63) x 0.80
= 38.47

(continued)

TABLE C-6. (Continued)

11. Total Labor Cost $(10^3\ \$)$	= Operating labor cost $(10^3\ \$)$ + supervisory labor cost $(10^3\ \$)$ + maintenance labor cost $(10^3\ \$)$ + overhead labor cost $(10^3\ \$)$ = 20.4 + 3.06 + 24.63 + 38.47 = 86.56
12. Electricity Cost $(10^3\ \$)$	= (electricity price) x (pressure drop) x (flow rate) x (flue gas:offgas ratio) x (fan equation conversion factor) x (# of hours per year) ÷ fan efficiency ÷ 1000 = 0.0279 $(\$/\text{KWhr})$ x 22 in. x 3.96 scm/min x 2.9 x 0.004136 (KW/scmin.) ÷ 0.6 ÷ 1000 $(\$/10^3\ \$)$ = 0.426
13. Quench Water Cost $(10^3\ \$)$	= (quench water price) x (flow rate) x (flue gas:offgas ratio) x (water required per unit flow) x (minutes per year) ÷ 1000 = 0.22 $(\$\ 10^3\ \text{gal})$ x 3.96 (scm/min) x 2.9 x 1.68×10^{-5} $(10^3$ gal/scm) x 0.5256 $(10^6$ min/yr) ÷ 1000 $(\$/10^3\ \$)$ = 0.0223

(continued)

TABLE C-6. (Continued)

14. Scrubbing Water Cost (10^3 \$)
= (scrub water price) x (flow rate) x (flue gas:offgas ratio) x (chlorine content of flue gas) x (water required per unit chlorine) x (# of hours per year)
= 0.22 (\$$10^3$ gal) x 3.96 (scm/min) x 35.314 scf/scm x 2.9 x 0.0487 (lb/hr chlorine)/(scf/min flue gas) x 0.0192 (10^3 gal/lb chlorine) x 8760 (hr/yr) ÷ 1000
= 0.73

15. Neutralization Cost (10^3 \$)
= (caustic cost) x (flow rate) x (flue gas:offgas ratio) x (chlorine content of flue gas) x (caustic requirement per unit chlorine) x (# of hours per year) ÷ 1000
= 0.0436 (\$/lb NaOH) x 3.96 (scm/min) x 35.314 scf/scm x 2.9 x 0.0487 (lb/hr chlorine)/(scf/min flue gas) x 1.14 (lb NaOH/lb chlorine) x 8760 (hr/yr) ÷ 1000 \$/10^3 \$
= 8.6

16. Heat Recovery Credit
= 0 (for all streams <700 scfm)

(continued)

TABLE C-6. (Continued)

17. Taxes, Insurance, and Maintenance Cost (10^3 \$)	= (installed capital cost) x (taxes, insurance, and administrative charges factor + maintenance labor factor) = 820.9 (10^3 \$) x (0.04 + 0.03) = 57.46
18. Annual Operating Cost (10^3 \$)	= (TI&M cost) + (gas cost) + total labor cost) + (electricity cost) + (quench cost) + (scrubbing cost) + (scrubbing cost) + (caustic cost) = 57.46 + 26.20 + 86.56 + 0.426 + 0.0223 + 0.73 + 8.6 = 180.00
19. Annualized Cost (10^3 \$)	= (operating cost) + (capital recovery factor x total installed capital cost) = 180.0 + (.163 x 820.9) = 313.8
20. Annual Emissions (Mg/yr)	= (hourly emissions) x 365 (days/yr) x 24 (hrs/day) x (Mg/10^3 kg) = 15.86 kg/hr x 365 (days/yr) x 24 (hrs/day) x 1 (Mg/10^3 kg) = 138.9
21. Annual Emission Reduction (Mg/yr)	= (annual emissions) x 0.98 = 138.9 x 0.98 (C_2HCl_3) = 136.1 (C_2HCl_3) = 349.6 (VOC)

(continued)

TABLE C-6. (Continued)

22. Cost Effectiveness (\$/Mg)	= (annual cost) ÷ (annual emission reduction) = 313.8 (10^3 \$) ÷ 136.1 Mg (C_2HCl_3) = 2305/Mg (C_2HCl_3) = 313.8 (10^3 \$) ÷ 349.6 Mg (VOC) = 898/Mg
23. Updated Cost-Effectiveness Values (\$/Mg)	= 2305 (\$/Mg) x 1.486 = \$3420/Mg (C_2HCl_3) = 898 (\$/Mg) x 1.486 = \$1330/Mg (VOC)

TABLE C-7. COST CONVERSION FACTORS FOR INCINERATOR COMPONENTS

Original Cost Component	Original Year	Conversion Year	Factor
Incinerator	1979	1978	0.900
Pipe Rack	1982	1978	0.745
Duct Work	1977	1978	1.088
Annualized Costs	1978	1984	1.486

b. Additional cost of adding secondary seal:[4]

Cost = \$580 x D

(The \$580 x D cost reflects using a Viton^R coating material for the secondary seal)

3. Door Sheet Opening Cost[6]

Cost = \$1,300

Total capital cost (primary seal) = degassing cost + estimated installed cost (2a) + door sheet opening cost.

Total capital cost (primary + secondary seals) = degassing costs + estimated installed cost (2a,b) + door sheet opening cost.

C.2.2 Annual Cost (4th Quarter 1982 Dollars)

1. Taxes, insurance, and administration -- 4% of capital cost (based on 10 percent interest rate and 10 year equipment life)
2. Maintenance -- 5% of capital cost
3. Inspection -- 1% of capital cost
4. Capital recovery factor -- 16.275% of capital cost

Total annual cost = [26.275% of capital cost]

C.2.3 C_2HCl_3/VOC Reduction

1. Emissions calculated for fixed roof tanks using AP-42 formulas.

2. Emissions calculated for internal floating roof tanks using AP-42 formulas.
    a. Liquid mounted primary seal only
    b. Liquid primary and secondary seal

3. Emissions from fixed roof tank - emissions from internal floating roof tank = VOC emission reduction

    C_2HCl_3 emission reduction = VOC emission reduction x percentage of C_2HCl_3 in stored material

C.2.4 Recovery Credits (4th Quarter 1984 Dollars)

Credits = (TCE emission reduction) x (4th Quarter 1984 TCE market value ($440/Mg) + [(TCE emission reduction - VOC emission reduction) x (4th Quarter 1984 VOC market value ($330/Mg))]

C.2.5 Net Annual Cost

Before annual cost can be calculated, all costing data is converted to 1984 dollars using Chemical Engineering Economic Indicators)

Cost = annual cost (4th quarter 1984 dollars) - VOC recovery credits (4th Quarter 1984 dollars)

C.2.6 Cost Effectiveness

C_2HCl_3 cost effectiveness = net annual cost/C_2HCl_3 emission reduction (Mg)

VOC cost effectiveness = net annual cost/VOC emission reduction (Mg)

C.3 COST CALCULATIONS FOR INSTALLATION OF REFRIGERATED CONDENSERS TO CONTROL LOADING AND STORAGE EMISSIONS

Cost estimates were developed for controlling handling and storage emissions at trichloroethylene production facilities based on refrigeration vapor recovery systems. A diagram of such a system is presented in Figure C-1. Cost information was obtained from the EPA publication "Capital and Operating Costs of Selected Air Pollution Control Systems."[3]

The vapor recovery system cost is based on the flow rate of air through the device. Using the Dow/Freeport handling operations information as the model, a sample calculation is presented below.

- Maximum flow rate = 110 cfm. From Figure 5-26 of Reference C-1, the December 1977 capital cost for the refrigerated vapor recovery unit (which includes a complete skid mounted package containing the refrigeration unit, a brine storage tank, two condensing units, pumps, valves, and controls), was estimated to be $63,700.

- Stainless steel fixtures were included to prevent corrosion at an additional cost of 130 percent of the capital cost. The cost of taxes, freight, and installation was estimated to be an additional 75 percent of the cost.

- Capital cost of the unit updated to November 84 is $63,700 x 2.3 x 1.74 x $\left(\frac{335.4}{262.2}\right)$ = $380,200.

- CE cost index for fabricated equipment: November 1984 = 335.4, December 1977 = 226.2.

- Operating labor cost was calculated as $15/hr x 180 hr = $2700/yr.

- Maintenance costs were calculated as 5 percent of the updated capital cost. 0.05 x $380,200 = $19,000/yr.

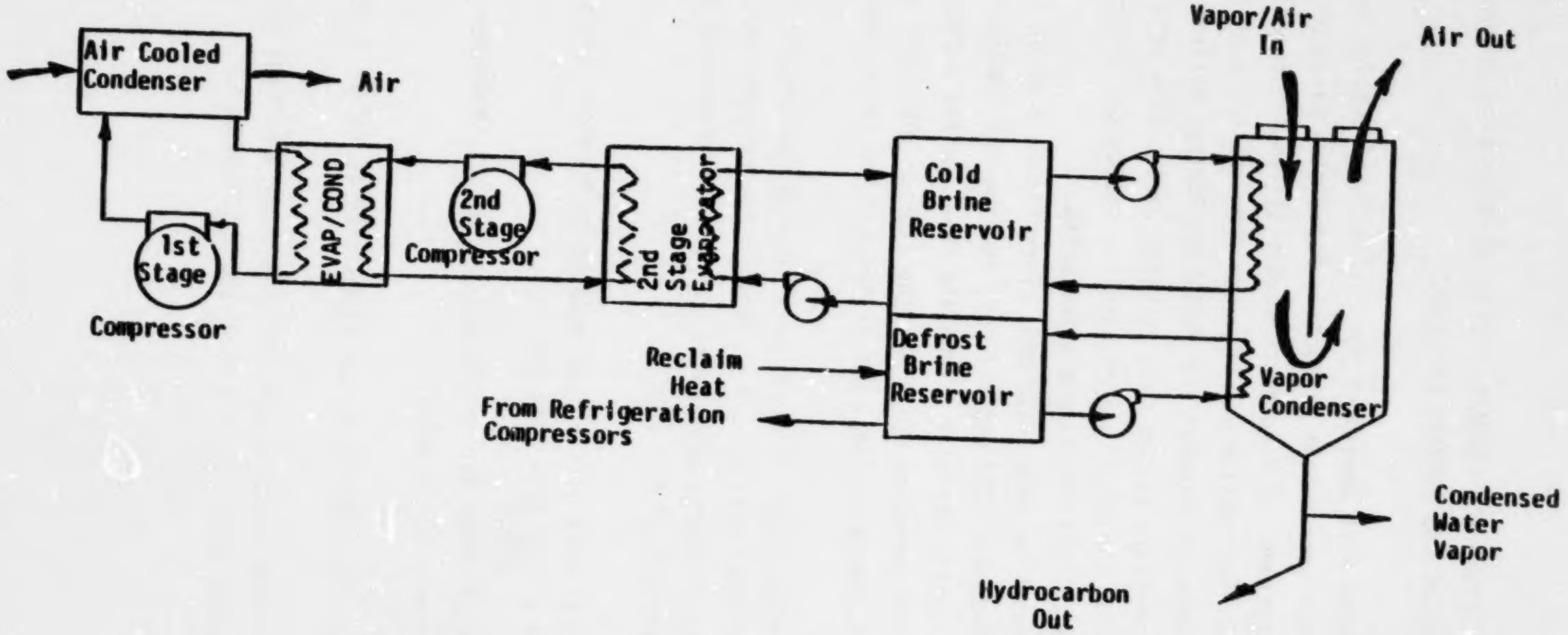

Air Cooled Condenser
Air
1st Stage Compressor
EVAP/COND
2nd Stage Compressor
2nd Stage Evaporator
Cold Brine Reservoir
Defrost Brine Reservoir
Reclaim Heat From Refrigeration Compressors
Vapor/Air In
Air Out
Vapor Condenser
Condensed Water Vapor
Hydrocarbon Out

Figure C-1. Cascade refrigeration system for vapor recovery.

- Electricity requirements were also based on Figure 5-26 of Reference B-1. Power requirements include brine pumps, compressor, condenser fan, controls, and instrumentation. With a utilization factor of 1.9 percent for Dow/Freeport's handling operations, November 1984 costs were estimated as 50 kW x 0.019 x 8,760 $\frac{\text{hr}}{\text{yr}}$ x $0.0506/kw-hr = $420/yr. An additional 20 percent was added to this to include electricity costs for the fan/blower and the produce recovery pump. Total electrical costs are estimated to be $420/yr x 1.2 = $500/yr.

- Capital charges were estimated as 22 percent of the updated capital cost of the system 0.22 x $390,200 = $83,600. These charges include yearly taxes, insurance, administration, etc.

- The annual cost of the system was calculated as the sum of the following costs: operating, labor, maintenance, electricity, and capital charges. $2,700 + 19,000 + 500 + 83,600 = $105,800/yr.

- A recovery credit of $440/Mg TCE recovered was applied to the annual cost of the system. A TCE emission reduction efficiency for the unit was based on the vapor pressure of TCE at the inlet conditions (27°C, 1.54 psia) and at the outlet conditions (-79°C, 0.0172 psia) and was estimated to be 90 percent for loading applications and 85 percent for storage tank applications. Recovery credit = $440/Mg x (10 Mg TCE inlet *90 percent removal) = $4,000/yr.

- Total annualized cost = $105,800 - $4,000 = $101,800.

- The total annualized cost for operating the system was calculated as (0.16275 x $380,200) + $101,800 = $165,600/yr.

- The cost effectiveness of the system was calculated as (\$163,700/yr)/(10 Mg x .90) = \$18,200/Mg.

C.4 SAMPLE CALCULATIONS FOR EQUIPMENT LEAK CONTROL COSTS

To calculate the cost for the implementation of technologies to control equipment leak emissions, the specific control techniques, removal efficiencies and capital/annualized costs per component are given in Table C-8. The equipment leak emission sources costed are pump seals, compressors, flanges, valves, pressure relief devices, sample connectors, and open ended lines.

Capital cost per emission source: (No. of components) x (capital cost per component)

Total capital cost per plant: Σ [capital cost per emission source] annual cost per emission source: (No. of components) x (annual cost per component)

C_2HCl_3 emission reduction per emission source: (current C_2HCl_3 emission) x (percent reduction)

Total C_2HCl_3 emission reduction per plant: Σ [C_2HCl_3 emission reduction per emission source]

VOC emission reduction per emission source: (current VOC emission) x (percent reduction)

Total VOC emission reduction per plant: Σ [VOC emission reduction per emission source]

Recovery credit per emission source: (TCE emission reduction for source i) x (4th Quarter 1984 TCE makret value (\$440/Mg) + [(TCE emission reduction for source i - VOC emission reduction for source i) x (4th Quarter 1984 VOC market value (\$330/Mg)].

TABLE C-8. CONTROL TECHNIQUES AND COST FOR CONTROLLING EQUIPMENT LEAK EMISSION SOURCES[a]
(4th Quarter 1984 Dollars)

Equipment Type (Emission Source)	Control Techniques	Percent Reduction[5]	Capital[6] Cost $/Component	Annualized[6] Cost $/Component
1. Pump seals				
- Packed	Monthly LDAR	61	0	370
- Mechanical	Monthly LDAR	61	0	370
- Double Mechanical	N/A	N/A	N/A	N/A
2. Compressors	Vent to combustion device	100	10,200	2,580
3. Flanges	None Available	N/A	N/A	N/A
4. Valves				
- Gas	Monthly LDAR	73	0	20
- Liquid	Monthly LDAR	59	0	20
5. Pressure Relief devices				
- Gas	O-Ring	100	310	80
- Liquid	N/A	N/A	N/A	N/A
6. Sample Connections				
- Gas	Closed-purge sampling systems	100	670	170
- Liquid	Closed-purge sampling systems	100	670	170
7. Open Ended Lines				
- Gas	Caps on open ends	100	70	20
- Liquid	Caps on open ends	100	70	20

[a] Updated to 4th quarter 1984 using CE index.

Recovery credit per plant: Σ [Recovery credit per emission source]

Net annual cost (C_2HCl_3) per emission source: (annual cost per emission source) minus (recovery credits per emission source).

Net annual cost (C_2HCl_3) per plant: (total annual cost per plant) minus (total recovery credits per plant).

Net annual cost (VOC) per emission source: (annual cost per emission source) minus (recovery credits per emission source).

Net annual cost (VOC) per plant: (total annual cost per plant) minus (total recovery credits per plant).

Cost effectiveness for controlling C_2HCl_3 emissions per emission source: (net annual cost (C_2HCl_3) per emission source) ÷ (C_2HCl_3 emission reduction per emission source).

Cost effectiveness for controlling C_2HCl_3 emissions per plant: (net annual cost (C_2HCl_3) per plant) ÷ (C_2HCl_3 emission reduction per plant).

Cost effectiveness for controlling VOC emissions per emission source: (net annual cost (VOC) per emission source) ÷ (emission reduction per emission source).

Cost effectiveness for controlling VOC emissions per plant: (net annual cost (VOC) per plant) ÷ (emission reduction per plant).

C.5 REFERENCES

1. U.S. Environmental Protection Agency. Control of Volatile Organic Compound Emissions from Air Oxidation Processes in Synthetic Organic Chemical Manufacturing Industry. Research Triangle Park, N.C. Publication No. EPA-450/3-84-015. December 1984. p. 510.

2. Memo from Pandullo, R. F. and I. A. McKenzie, Radian Corporation, to Air Oxidation Processes and Distillation Operations Project Filtes. May 3, 1985. 20p. Revision to the Incinerator Costing Procedures Used for the Proposed Air Oxidation and Distillation NSPS.

3. Neveril, R. B. (GARD, Inc.). Capital and Operating Costs of Selected Air Pollution Control Systems. (Prepared for the U.S. Environmental Protection Agency.) Research Triangle Park, N.C. Publication No. EPA-450/5-80-002. December 1978. pp. 5-65 through 5-71.

4. Atkinson, R. D. (MRI) et al. Source Assessment of Ethylene Dichloride Emissions. (Prepared for the U.S. Environmental Protection Agency.) Research Triangle Park, N.C. EPA Contract No. 68-02-3817. September 1984.

5. U.S. Environmental Protection Agency. Fugitive Emission Sources of Organic Compounds - Additional Information Document. Research Triangle Park, N.C. Publication No. EPA-450/3-82-010. April 1982. p. 1-4.

6. U.S. Environmental Protection Agency. Benzene Fugitive Emissions - Background Information for Promulgated Standards. Research Triangle Park, N.C. Publication No. EPA-450/3-80-032b. June 1982. Appendix A.

D.1 EXISTING STATE REGULATIONS

D.1.1 Introduction

Trichloroethylene emissions originate from several industrial sources. These sources include producers of C_2HCl_3, sources that use C_2HCl_3 as a chemical intermediate, and sources that store C_2HCl_3. These emissions can be characterized as either process, fugitive, or product storage tank emissions.

There are a number of different regulations at the State level that limit C_2HCl_3 emissions. C_2HCl_3 emissions in nonattainment areas (areas that have not achieved the ambient air quality standards for ozone) are normally controlled by the States' RACT program. C_2HCl_3 emissions in areas designated as attainment or unclassified for ozone are controlled by Prevention of Significant Deterioration (PSD) regulations. In addition to the RACT and PSD programs, 12 States (including the District of Columbia) have general VOC regulations that limit emissions of photochemically reactive compounds.

D.1.2 General State VOC Regulations for Solvent Use

Table D-1 presents a list of the States that have adopted a general VOC solvent usage regulation and the emission limits established by each State. These regulations affect volatile organic solvents found to be photochemically reactive and usually require 85 percent reduction in VOC emissions. Sources emitting C_2HCl_3 are currently covered by these regulations.

D.1.3 Prevention of Significant Deterioration Regulations

PSD regulations control VOC emissions from major sources in areas classified as attainment for ozone. Under PSD regulations, a chemical production plant must seek a PSD permit if it is: (1) a new source and emissions or potential emissions are considered major (100 tons/yr); (2) a major increase in emissions or potential emissions (100 tons/yr) at an existing minor source; or (3) a significant increase in emissions or potential emissions (40 tons VOC/yr) at an existing major source. Emission control levels for PSD are established during the State's review of the PSD permit application prepared for the emission source.

TABLE D-1. GENERAL STATE VOC REGULATIONS FOR PHOTOCHEMICAL SOLVENTS

State	Emission Reduction (%)
California	85
Colorado	85
Connecticut	85
District of Columbia	85
Illinois	85
Indiana	85
Louisiana	90
Maryland	85[1]
North Carolina	85
North Dakota	85
Rhode Island	85[2]
Virginia	85

[1] Applies to sources in nonattainment areas only.

[2] Applies to sources emitting less than 100 tons/year, larger sources must comply with RACT.

D.1.4 State Regulations Affecting Chemical Production

In addition to the general discussion of State regulations concerning C_2HCl_3 emission sources, a more indepth review was performed for States in which C_2HCl_3 production facilities are located. These findings are presented in Table D-2. Other VOC emissions at these facilities may also be controlled.

D.2 EXISTING FEDERAL REGULATIONS

Several VOC NSPS and a NESHAP have been developed that could affect new and some existing sources of C_2HCl_3 emissions. A summary and the current status of each of these standards are presented in Table D-3.

TABLE D-2. STATE REGULATIONS AFFECTING CHEMICAL PRODUCTION FACILITIES

State	Source	Regulation
Kansas	No regulations for control of VOC emissions from chemical production facilities	
Louisiana[1]	Storage tanks >40,000 gal Vapor pressure ≤11.0 psia and ≥1.5 psia.	- Pressure tank or - An internal floating roof with a closure seal & submerged fill pipe - An external floating roof with secondary seal and submerged fill pipe - A vapor loss control system & submerged fill pipe
	Storage tanks >250 gal ≤40,000 gal	- Submerged fill pipe with vapor recovery system
	VOC loading facilities servicing tanks, trucks or trailers having a capacity of >200 gal & throughput ≥20,000 gal/day (40,000 gal/day for existing facilities)	- Vapor collection & disposal system
	Pumps, compressors, valves, etc. (≥1.5 psia vapor pressure compounds)	Equipped with mechanical seals & maintained to prevent leaks
	Waste gas disposal containing organic compounds from any emission source including process unit upsets, start-ups and shutdowns.	Halogenated hydrocarbons shall be burned & the products of combustion subsequently controlled. Other methods such as carbon adsorption, refrigeration, catalytic/thermal reaction can be substituted. Provisions may be waived if gas stream <100 T/yr, will not support combustion without auxiliary fuel, or control will cause economic hardship

TABLE D-2. (Continued)

State	Source	Regulation
Louisiana (cont.)	Facility emitting >1.4 kg/hr or 6.8 kg/day of VOC	- Must reduce emissions either by incineration (90% removal efficiency) or by carbon adsorption system. During process upsets, start-ups, or shut downs, VOC emissions must be vented and reduced either by an afterburner, carbon adsorption system, refrigeration, catalytic and/or thermal reduction, secondary steam stripping, or vapor recovery system.
Illinois[1]	Storage tanks >40,000 gallons	- Pressure tank or - Floating roof - Vapor recovery system with 85 percent recovery - Equipment or means of equal efficiency
	VOC loading facilities servicing tanks, trucks or trailers having capacity of >250 gal and throughput >40,000 gal/day.	- Submerged loading or - Equivalent control
Texas[1]	Storage tanks vapor pressure $\geq$1.5 psia, <11 psia	
	$\leq$1000 gal	- None
	$\geq$1000 gal <25,000 gal	- Submerged fill pipe
	>25,000 gal $\geq$42,000 gal	- Internal or external floating roof with primary & secondary seal, or vapor recovery system
	VOC loading and unloading (facilities with >20,000 gal/day throughput of $\geq$1.5 psia VOC)	Vapor recovery system

TABLE D-2. (Continued)

State	Source	Regulation
Texas (cont.)	Vent gas control (≥0.4 psia and emissions >100 lbs/24hr or >250 lb/hr averaged over 24 hours)	Flared or incinerated at 1300°F
	SOCMI Fugitive VOC (Harris County)	No compound shall be allowed to leak with a VOC concentration >10,000 ppm (time limits given)
	Storage tanks containing vinyl chloride	Concentration of exhaust gases discharged to the atmosphere from storage tanks must not exceed 10 ppm (NESHAP - Vinyl Chloride)

[1] Environment Reporter, State Air Laws. Washington, D.C. Bureau of National Affairs.

TABLE D-3. SUMMARY OF FEDERAL REGULATIONS AFFECTING TRICHLOROETHYLENE EMITTING SOURCES

Source	Proposed	Promulgated
SOCMI Equipment Leaks (Fugitive) NSPS	01/05/81	10/18/83
VOL Storage Vessels NSPS	10/84	
SOCMI Air Oxidation NSPS	10/21/83	
SOCMI Distillation Operations NSPS	12/30/83	
SOCMI Reactor Processes NSPS[a]	-	

[a] Currently draft standards.

E-1 TRICHLOROETHYLENE EMISSIONS FROM DISTRIBUTION FACILITIES

(1) Estimate the quantity going through distribution (storage)

1983 approximate production = 200 MM lbs

Assume that all TCE goes through distribution

(2) Estimate the number of storage tanks nationwide

- Assume the average tanks size is 10,000 gallons
- Assume the average turnover time is 1 month

$$\text{Number of tanks} = 356 \text{ MM lbs} \left(\frac{\text{gal}}{12.3}\right)\left(\frac{1 \text{ tank}}{10{,}000 \text{ gal} \times 17}\right) = 96 \text{ tanks}$$

(3) Estimate storage emissions (fixed roof tanks)

Breathing Loss

$$L_B = 1.02 \times 10^{-5} M_v \left(\frac{P}{14.7-P}\right)^{0.68} D^{1.73} H^{0.51} T^{0.5} F_p C K_x$$

$$L_B = 1.02 \times 10^{-5} (133) \left(\frac{0.5}{14.7-0.8}\right)^{0.68} (10)^{1.73} (9)^{0.51} (1.15)(0.5)(1.0)$$

$$L_B = 0.018 \text{ Mg/yr}$$

Working Loss

$$L_W = 1.09 \times 10^{-8} M_v P V N K_n K_c$$

$$L_W = 1.09 \times 10^{-8} (133)(0.8)(10{,}000)(17)(1)(1)$$

$$L_W = 0.197 \text{ Mg/yr}$$

Total Loss

$$L_T = L_B + L_W = 0.22 \text{ Mg/yr per tank}$$

Total nationwide storage emissions = (0.22)(96) = 21 Mg/yr where:

M_v = molecular weight of product vapor (lb/lb mole)

P = true vapor pressure of product (psia)

D = tank diameter (ft)

H = average vapor space height (ft)

T = average diurnal temperature change (°F)

F_p = paint factor (dimensionless); 1.0 for clean white paint

C = tank diameter factor (dimensionless):

for diameter $\geq$ 30 feet, $C = 1$
for diameter $\leq$ 30 feet, $C = 0.771D - 0.013D^2 - 0.1334$

K_c = product factor (dimensionless) = 1.0 for VOL

V = tank capacity (gal)

K_n = turnover factor (dimensionless):

for turnovers > 36, $K_n = \frac{180 + N}{6N}$

for turnovers $\leq$ 36, $K_n = 1$

(4) Estimate container filling emissions

Loading Loss

$$L_L = 12.46 \frac{S\ P\ M}{T}$$

where: S = saturation factor (0.50 for submerged fill and 1.45 for splash fill)

P = True vapor pressure, psia

M = Molecular weight

T = Temperature, °R

Assume 50 percent splash filling (S = 1.0)

$$L_L = 12.46 \frac{(1.0)(0.8)(133)}{530} = 2.5 \text{ lb}/10^3 \text{ gal}$$

$$= 1.13 \text{ lb}/10^3 \text{ gal}$$

$$200 \text{ MM lb} \left(\frac{\text{gal}}{12.3 \text{ lb}}\right)\left(\frac{1.13 \text{ kg}}{10^3 \text{ gal}}\right) = 18 \text{ Mg/yr}$$